AD-A261 233

(12)

USAATCOM TR 93-D-1

U.S. ARMY AVIATION
AND TROOP COMMAND

PROAV CABLE WARNING SYSTEM (CWS) - U.S. ARMY AIRCRAFT INTEGRATION ASSESSMENT AND OCONUS FIELD EVALUATION

Kent F. Smith and MAJ Eric C. Littleton

February 1993

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AVIATION APPLIED TECHNOLOGY DIRECTORATE
U.S. ARMY AVIATION AND TROOP COMMAND
FORT EUSTIS, VA 23604-5577

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
February 1993

3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE
PROAV Cable Warning System (CWS) - U.S. Army Aircraft Integration Assessment and OCONUS Field Evaluation

5. FUNDING NUMBERS

6. AUTHOR(S)
Kent F. Smith and MAJ Eric C. Littleton

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Aviation Applied Technology Directorate
U.S. Army Aviation and Troop Command
Fort Eustis, VA 23604-5577

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
USAATCOM TR 93-D-1

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The PROAV Cable Warning System (CWS) is a commercially available system designed to detect the electromagnetic field generated by current-carrying wires operating at frequencies of either 50 or 60 Hz. The system is designed to alert helicopter crewmen to the presence of these wires to help prevent wire strike mishaps. As directed by the U.S. Army Aviation and Troop Command, the Aviation Applied Technology Directorate performed an aircraft integration assessment of the CWS followed by field evaluations in Germany and Korea. These field evaluations were not operational tests, since no standard or specification exists by which to judge this system. The CWS was successfully integrated on the AH-64A, AH-1F, and UH-1H aircraft. During the field evaluations, the CWS was flown a total of 207 hours by 40 different pilots. The conclusions were that the CWS was not consistent in its ability to detect wires and provide sufficient reaction time and that pilot confidence in the capabilities of the CWS was marginal to low. Also, significant aircraft integration issues remain unresolved for several U.S. Army fleet aircraft.

14. SUBJECT TERMS Wire Strike, Wire Avoidance, Obstacle Avoidance, Wire Detector, Cable Detector, Powerline, Obstacle Warning, Nap-of-the-Earth, Electromagnetic Field, Electromagnetic Detector, Electromagnetic Flux Field, Wire Sensor, Cable Sensor, Wire Hazard

15. NUMBER OF PAGES
123

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	

PREFACE

This report describes the work performed by the Aviation Applied Technology Directorate (AATD), U.S. Army Aviation and Troop Command (ATCOM), in evaluating a commercially available cable warning system (CWS) as a safety device to aid Army aircrewmen in avoiding power lines. ATCOM sponsored the work conducted under contract DAAJ02-91-C-0040, "PROAV Cable Warning System Evaluation." The authors wish to express appreciation to the individuals in the U.S. Army Aviation Logistics School (USAALS) who provided aircraft and pilot assistance in support of this contract.

The U.S. Army Materiel Command (AMC) sponsored the work conducted under contract DAAJ02-91-C-0061, "Cable Warning System and Technical Support for Field Evaluation." The authors wish to express appreciation to the individuals in the AMC Field Assistance in Science and Technology (FAST) offices for their outstanding support to AATD in carrying out the field evaluations in Germany and Korea. These individuals were Mr. Allen Christenson and Dr. Joyce Illinger in Germany and Messrs. Jim Gibson and Bob Stern in Korea.

The authors also wish to thank Dr. Paul Rose and his associates of the U.S. Army Human Engineering Laboratory (HEL) for their invaluable expertise in the design of the pilot questionnaire for the field evaluations and the final data analysis.

The technical and logistical support required in this program was extensive and complex, and the authors wish to express appreciation to those individuals at AATD who provided this support.

Mr. Kent F. Smith of the Safety and Survivability Division served as Project Engineer and MAJ Eric C. Littleton of the Flight Projects Office served as Flight Test Director for AATD.

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BACKGROUND

The Center for Night Vision and Electro-Optics, Communications and Electronics Command (CECOM), Fort Belvoir, Virginia, tested the PROAV Cable Warning System (CWS) at Fort Rucker, Alabama, in July 1989. Testing was conducted using an extensively modified AH-1S test aircraft equipped with the CWS. As this had been designated as a test aircraft for some time, it had no fire control system avionics or 20mm nose gun. This caused it to differ considerably from the fielded AH-1F models evaluated in this report. The presence of these systems on the AH-1Fs may or may not account for integration difficulties experienced and reported herein. The final results of the July 1989 testing by CECOM were reported in Reference 1.

The conclusions of the CECOM evaluation stated that the system worked as advertised; however, it should not be used as a stand-alone wire avoidance sensor. This was largely due to the frequent alarm problem caused by active wires in areas of even modest population density, such as lower Alabama. Also, variations in electricity demand resulted in unpredictable detection ranges. CECOM recommended that a follow-on operational test be conducted. However, ATCOM, based on mixed pilot opinions on later communications with the Directorate for Combat Developments, Fort Rucker, tasked AATD to conduct an in-house flight evaluation of the CWS before recommending operational tests.

The CWS was installed on an OH-58A/C aircraft (A model with a C engine) in November 1989 at Fort Eustis, Virginia. Technical difficulties were encountered at that time during the calibration flights, precluding any further testing. These difficulties related to strong electromagnetic source(s) apparently emanating from parts of the OH-58A/C engine or drivetrain which caused the CWS to constantly alarm. Integration of the CWS in its current configuration with the OH-58A/C was technically not feasible.

The Canadian government expressed interest in supporting the CWS in a Defense Development Sharing Program (DDSP) with the Advanced Systems Directorate (ATCOM) in the fall of 1990. AATD was requested to formulate and submit a CWS flight test evaluation plan for the AH-64A, UH-60A, AH-1F, UH-1H, CH-47D, and OH-58A to ATCOM for its DDSP negotiations with the Canadian government. In February 1991, AATD was tasked to conduct a CONUS evaluation at Fort Eustis and a no-cost contract was established with PROAV International Aviation Services Corporation for their technical support with the CWS installations. On 19 August 1991, after completion of this work and a briefing to HQ, AMC, AATD was directed to conduct a field evaluation of the CWS outside the Continental United States (OCONUS) in Germany and Korea. A contract for purchase of 10 CWS units and technical services was let to the Canadian Commercial Corporation (representing the Canadian government), who subcontracted this effort with PROAV.

EVALUATION OBJECTIVE

The objective of this program was to evaluate the PROAV CWS on standard Army helicopters to determine its capability to detect and provide effective warnings of energized power line hazards to flight crews operating in the terrain and otherwise low-altitude flight environments.

DESCRIPTION OF TEST ARTICLE

The PROAV CWS is a nondevelopment item (NDI) designed to detect the magnetic field surrounding current-carrying power lines and provide flight crews with an aural warning through the aircraft intercom system ("wires, wires, wires") and a visual display indicating relative bearing to the wires. In the case of intersecting wires, the system senses the sum of the magnetic fields and indicates a bearing to the resultant field. The CWS will detect only active power lines, is completely passive, and consists of the following three line replaceable units (LRUs): the Sensor Unit, the Automatic Voice Alerting System, and the Cockpit Display Unit. The physical and electrical characteristics of the CWS LRUs are presented in Table 1.

TABLE 1. PHYSICAL AND ELECTRICAL CHARACTERISTICS OF THE CABLE WARNING SYSTEM

COMPONENT	SIZE (IN)	WEIGHT (LB)	POWER CONSUMPTION (WATTS)
SENSOR UNIT	7.5 X 7.5 X 4.7 (W/VIB ISOLATION)	8.0	4
VOICE ALERTING UNIT	1.1 X 2.0 X 4.4	0.3	5
COCKPIT DISPLAY UNIT	2 X 2 X 5.5	1.0	3
CABLE, CONNECTORS	AS REQUIRED	4.6 (EST)	---
TOTALS	---	~14	12

The CWS can be set to detect either 50 or 60 Hz magnetic fields. Detection distance is primarily a function of the level of current in the wires and the preset threshold sensitivity of the CWS. Once the magnetic threshold level is sensed by the CWS, the aural alert sounds and the cockpit display illuminates to indicate bearing information. As long as the aircraft remains within a magnetic field which exceeds the threshold level, the cockpit display will remain illuminated and continue to display bearing information; however, a new aural alert will not be given until the aircraft is clear of the magnetic field and the system automatically resets itself. Thus, overlapping magnetic fields from multiple wire sets require some vigilance on the part of the crew, as a new aural alert may not occur while approaching each successive set. The pilot can select either a minimum or maximum sensitivity via a switch on the display unit. In addition, the automatic voice alerting system can be muted by the pilot for operations at altitudes where wires are not a threat. A built-in test function is also incorporated and is activated via a button on the cockpit display. The system is powered by 28 volts dc. The

sensor unit and automatic voice alerting system were co-located in the aircraft tail boom for these tests. The CWS sensor unit mounting locations for each aircraft type are as follows:

Aircraft	Fuselage Station (in)
AH-64A	417
UH-60A	515
UH-1H	420
AH-1F	430
OH-58A	215

SCOPE OF EVALUATION

This report presents the results of a two-phase effort to evaluate the CWS. Phase One was the Continental United States (CONUS) evaluation at Fort Eustis and consisted of the integration of the CWS into the test aircraft and an engineering flight evaluation. This evaluation spanned from May through August 1991, in accordance with AATD's Flight Test Evaluation Plan for the PROAV Cable Warning System.[2] AATD provided the aircraft, hardware (except CWSs), and technical personnel required to install the test articles on all aircraft, and PROAV provided the CWSs and technical support under the Phase One contract. During this phase, 35.5 flight hours were accumulated in the AH-64A, AH-1F, UH-1H, UH-60A, and OH-58A. The CH-47D was not flown due to problems encountered during the airframe screening process (see Step 2, page 8).

Phase Two was the OCONUS field evaluation and consisted of in-depth pilot qualitative evaluations in Germany and South Korea. The Phase Two evaluations were conducted in accordance with AATD's Field Evaluation Plan for the PROAV Cable Warning System (Appendix A) and 207 flight hours were accumulated in the AH-64A, AH-1F, and UH-1H.

Schedules of the CONUS and OCONUS evaluations are shown in Figures 1a and 1b, respectively. The aircraft were operated in accordance with their respective operator's manuals[3-8] and airworthiness releases issued by AATD and ATCOM.[9-16] AATD provided the aircraft, hardware, and technical personnel required to install the test items on all aircraft and PROAV provided technical support under the Phase Two contract. Phase One aircraft were maintained by the respective provider, AATD or USAALS, and Phase Two aircraft were maintained by the respective aviation units in Germany or Korea. Qualitative data were collected using the Field Evaluation Pilot Questionnaire (contained in Appendix A) developed by AATD and HEL.

Since it was beyond the scope of this program, the objective did not include any investigation into the precise nature of magnetic fields (flux density mapping at various distances from the source, for example), neither those surrounding current-carrying wires nor those that may be generated on board by the various Army aircraft evaluated. Likewise, no attempt was made to assess any atmospheric or other environmental effects on these magnetic fields which may affect the performance of the system being evaluated. In each case, the evaluations were an attempt to assess actual CWS performance in a real-world flight environment where it is recognized that numerous electromagnetic field variables exist.

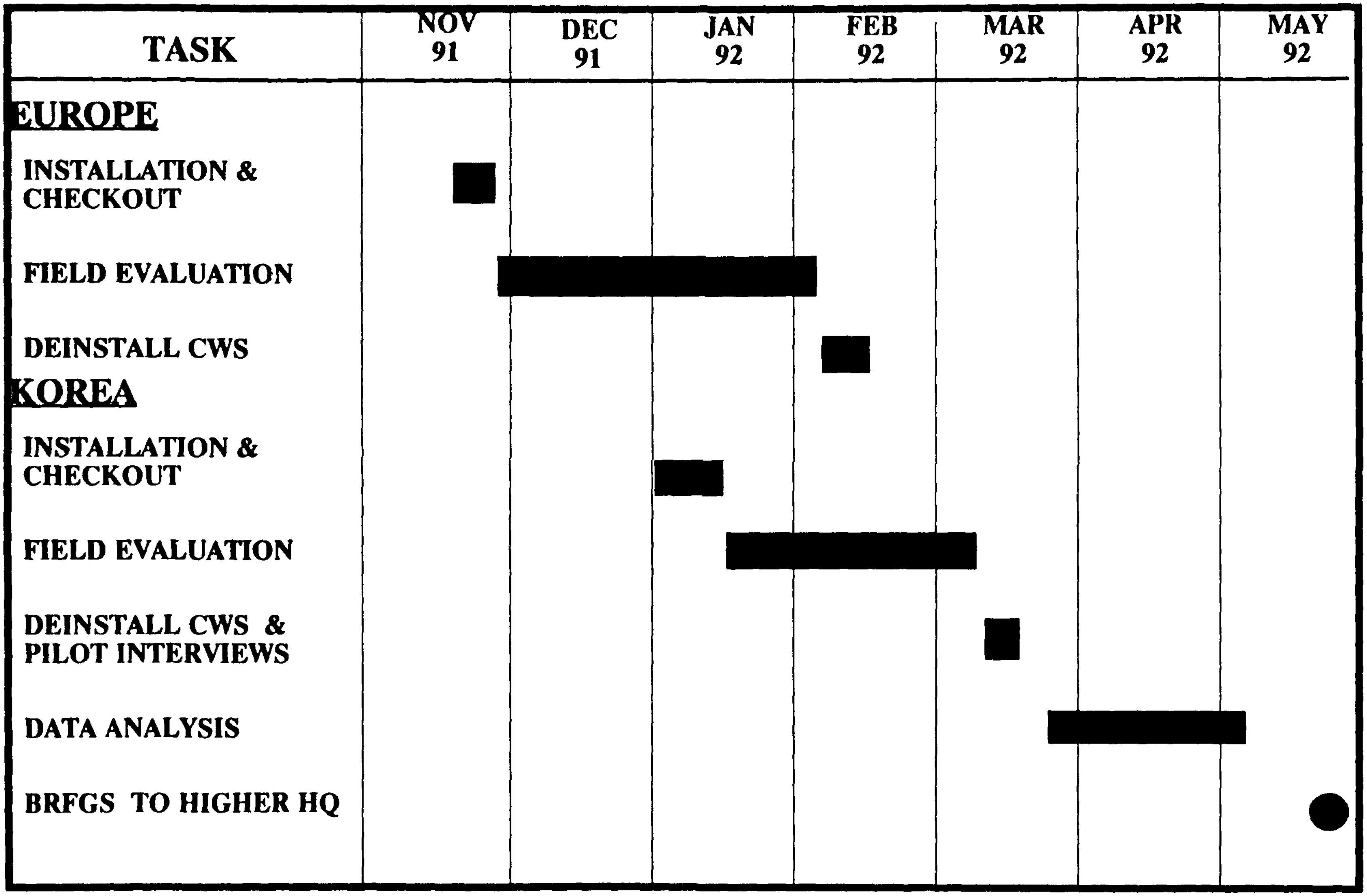

Figure 1b. CWS OCONUS evaluation schedule.

CONUS EVALUATION

The CONUS evaluation of the CWS was conducted in two parts. Part One consisted of the integration of the CWS into the host aircraft. The system was installed, checked, and adjusted in preparation for its evaluation. Part Two consisted of an engineering flight evaluation to provide limited documentation of system performance and to determine potential system utility in the terrain flight environment. These flights included various pilots from USAALS that assisted in obtaining a pilot's perspective of the CWS performance.

INTEGRATION

The integration phase consisted of a five-step procedure designed to ensure optimum installation, proper operation, and electromagnetic compatibility with the host aircraft, and to establish system threshold and gain settings. A PROAV technical representative (under contract) was involved during all aspects of the integration procedure. This representative was responsible for performing the unique aspects of the integration, such as the aircraft mapping and airframe screening check, and was the final authority in deciding when proper CWS integration had been achieved. Each step in the integration process is described below, followed by the results of the integration effort for each individual aircraft:

Step 1 - Aircraft Mapping: The objective of this step was to determine the optimum location of the CWS sensor within the aircraft. With the aircraft on the ground at 100% rotor speed and all in-flight systems turned on, the contractor surveyed the aircraft using a single coil magnetometer identical to those in the CWS sensor unit. Noise readings were taken throughout the aircraft to find a geometrically suitable location with minimum aircraft- induced magnetic field.

Step 2 - Airframe Screening Check: The objective of this step was to determine how the airframe attenuates and distorts an external magnetic field. The information gained was used to determine CWS processor gain adjustments. The aircraft was located approximately 100 feet from a 50-Hz electrical source, consisting of a 30-Kw generator with 300 feet of #4 AWG wire running out and back from an area lighting set designed to draw approximately 10 amps of current. The aircraft bearing relative to the electrical source was varied through 360 degrees in 45-degree increments, and measurements were made at the proposed sensor location using the single coil magnetometer described in step 1. CWS processor gains were adjusted to balance the output for proper wire alerts and relative bearing information during system use.

Step 3 - Electromagnetic Interference (EMI) Check Flight: The objective of this step was to ensure that the CWS did not interfere with the normal operation of any aircraft systems. With the CWS installed and operating, all appropriate aircraft systems were cycled on and off to confirm proper operation. The checks were conducted on the ground at 100% rotor speed and in flight.

Step 4 - CWS Adjustment Flights: The objectives of this step were to adjust CWS alert thresholds above any aircraft component-induced magnetic field that could cause the CWS to signal a false alarm; to confirm or correct CWS bearing output information; and to obtain a

preliminary look at system warning times. This was an iterative process usually requiring several flight and adjustment cycles to complete. The flights were initially conducted in the 60-Hz mode, and then thresholds were confirmed in the 50-Hz mode.

The aircraft was flown out over the James River away from any external magnetic field sources (i.e., power lines, electric power plants). The contractor monitored the CWS outputs using a breakout box specifically designed to provide access to all three output channels as well as the summed longitudinal and lateral channels. The aircraft was maneuvered throughout its speed range, and turns were conducted to determine the effect of maneuvering on an aircraft-generated electromagnetic field. The aircraft was then flown toward the power lines at the James River bridge, Newport News, Virginia, at various relative bearings to the wires to check the CWS bearing output indications. A qualitative assessment was also made of warning times at the bridge to provide a preliminary judgement of warning time adequacy. At the contractor's request the aircraft was returned to the airfield at various times throughout this process for gain or threshold adjustments.

Step 5 - Final Integration Check Flight: The objective of this step was to ensure that the CWS would operate properly and free of false alerts throughout its projected flight envelope. The aircraft was flown in an area free of any external electromagnetic sources. Airspeed was varied incrementally from zero to velocity-never-to-exceed (V_{ne}), left and right turns were conducted incrementally to 60 degrees angle of bank, and climbs and descents were conducted at representative airspeeds in an incremental fashion from maximum power climbs to engines-coupled autorotation.

AH-64A Integration

During the EMI check flight, it was noted that movement of the stabilator in either the manual or automatic mode resulted in a magnetic field-generated CWS output on the order of 1.5 volts. This characteristic was present on the ground and in flight and was determined to exceed reasonable CWS thresholds (typically on the order of 0.5 volt), resulting in unacceptably high false alert rates. It was determined that the stabilator control wires running along either side of the upper tail-boom area were the most likely source of the EMI due to their proximity to the CWS sensor unit.

Several steps were taken to isolate and rectify the problem, with negative results. First, the stabilator control wiring was shielded in the vicinity of the sensor unit and approximately 3 feet aft using an aluminum tape material. This was ineffective, and it was later determined that aluminum material provides negligible magnetic field attenuation in the 50- to 60-Hz frequency range. Second, the contractor surveyed other geometrically suitable areas in an attempt to find an alternate location for the sensor. The magnetic field problem existed throughout the airframe and no alternate area could be located. Third, a backup control system (BUCS) active aircraft was surveyed to determine if the increased EMI shielding in the BUCS aircraft attenuated the problem. No attenuation was noted because the shielding material used provides attenuation at much higher frequency levels than required (i.e., 400 Hz vs 50 or 60 Hz).

The solution to the problem was twofold. First, the stabilator wires were replaced with a twisted triplet configuration that moved the system ground from the airframe near the stabilator actuator to a location forward of the CWS sensor unit. Second, the twisted triplet was wrapped in a Mumetal tape (0.004 inch thickness) from the stabilator actuator to the bulkhead at the forward end of the tail boom. Integration was then continued with the modified stabilator wiring with no further incidence of stabilator-induced magnetic field.

During a subsequent adjustment flight, it was noted that the bearing information provided to the display unit was in error, in that relative bearing did not change from the straight-ahead indication to the 45-degree indication until the aircraft heading was approximately 80 degrees from a heading perpendicular to the cables. The proposed solution to this problem was to replace a resistor in the processor unit rather than make a gain adjustment, which would likely result in a higher false alarm rate. Testing was terminated prior to evaluating the proposed solution to the bearing problem due to aircraft maintenance problems; however, based on the results of testing prior to aircraft grounding, it was decided to proceed with the OCONUS evaluation program and make a final determination of integration success in Germany.

Later, following the OCONUS installations, it was determined that the resistor replacement had indeed solved the bearing indication problem.

UH-60A Integration

Two problems remain unresolved from the UH-60A integration effort. The first problem involves a magnetic field generated by the stabilator system. During the first adjustment flight, random false alerts occurred in the 50-Hz mode of operation. Further investigation showed CWS outputs on the order of 1.5 to 2.0 volts, exceeding any reasonable alert threshold (typically on the order of 0.5 volt). The source of the offending magnetic field was isolated to the stabilator system. When the stabilator system was placed in the manual mode and left static, the magnetic field and corresponding false alerts ceased. Resetting the stabilator system to the automatic mode resulted in the resumption of the false alerts.

The second problem is the presence of intermittent false alerts during turning flight. During a series of turns at various airspeeds to angles of bank from 15 to 60 degrees, the CWS alerted in a random fashion. In some cases, alerts occurred during the initiation of the turn. In other cases, alerts occurred after the angle of bank had been established; occasionally no alert occurred at all. Isolation of the source of the problem was attempted by conducting turns with the following systems disabled: Flight Path Stabilization (FPS), Stability Augmentation Systems (SAS) I and II, Trim, Boost, Stabilator, Transponder, Radar Altimeter, and all radios. In addition, the sensor mounting bracket was stiffened and the sensor isolation mounts were lengthened due to concerns that aircraft vibration was being transmitted to the sensor. In all cases the random alerts continued to occur.

A flight was conducted with a digital waveform analyzer instrumentation package on board the test aircraft. The package was designed to monitor CWS output signals. Turns were flown which resulted in the false alerts and data recorded. A frequency response analysis of the data was performed via fast Fourier transform in an attempt to isolate the source of the offending

magnetic field. The data collection and reduction failed to provide a conclusive indication of the source of the magnetic field and the problem remains unresolved.

The stabilator-induced magnetic field and the random alerts during turning flight will result in an unacceptably high false alert rate during flight; therefore, the integration of the CWS on the UH-60A is incomplete and will require additional effort.

AH-1F Integration

During adjustment flights, random CWS alerts occurred in the 50- and 60-Hz modes of operation. CWS output voltages oscillated randomly from approximately 0.25 to in excess of 2.0. In an attempt to isolate the source of the problem, the following systems were disabled: Tow Control Panel (TCP), Master Arm Switch, all armament circuit breakers, Doppler Navigation System, Radar Altimeter, Heads-Up Display (HUD), Transponder, and all radios. In all cases the alerts continued to occur. At the suggestion of the contractor, the CWS sensor unit was replaced. The problem was eliminated for 6.3 flight hours and then began to recur on a more intermittent basis. Further attempts to isolate the source of the magnetic field were unsuccessful.

Given the intermittent nature of the problem, the decision was made to proceed to the pilot evaluation phase in an attempt to gain some system effectiveness information. During the final integration check-flight prior to pilot evaluation, as airspeed was slowed to 80 KIAS from 110 KIAS, the CWS alerted. Output voltages varied from approximately 300 mV up to 1.5 to 2.0 volts. Power was varied in an attempt to isolate the problem, and there appeared to be a correlation between an N1 of 90% and problem occurrence. Small variances (±1%) of about 90% N1 reduced CWS outputs to 0 to 150 mV, which was considered normal.

During the next flight the above problem was not present; however, a more constant voltage on the order of 3.0 was noted. Attempts to isolate the source of the problem resulted in the voltage dropping back to normal levels as the 20mm gun turret drive motor circuit breaker was pulled out. The decision was made to proceed with the pilot evaluation with the turret drive motor circuit breaker out. The problem of intermittent output voltages of up to 2.0 remained unresolved; however, the decision was made to continue with the OCONUS flight evaluation to determine if the problem was specific to the airframe being used at Fort Eustis.

The problem was not noted during the OCONUS evaluation. Integration of the CWS on the AH-1F is therefore complete and integration problems encountered on the CONUS AH-1F must have been unique to that particular airframe.

UH-1H Integration

During the adjustment flight in the 50-Hz mode, in 30-degree angle of bank turns (left and right) with torque at 25 psi and N1 at 93%, the CWS alerted approximately every 5 to 10 seconds with output voltages on the order of 1.1. An increased 2-per-revolution vibration was noted under these conditions. An N1 sweep from 85% to 100% (torque from 5 to 41 psi) at 70 KIAS was conducted with no incidence of the false alerts or increased vibration level. With N1 held at 93% (torque at 25 psi), an airspeed sweep was conducted from 70 to 100 KIAS.

At approximately 95 KIAS an increased 2-per-revolution vibration was noted and the CWS began to alert as noted above.

A flight was conducted using the aircraft vibration analyzer (AVA) in accordance with standard maintenance procedures to document the vibration levels. The aircraft vibration levels exceeded the normal maintenance standards and a track and balance was conducted in accordance with normal maintenance procedures. During subsequent adjustment flights, the vibration and false alerts were noted only during extended (4 seconds or longer) stabilized turns at 45 degrees angle of bank and 95 KIAS. It was judged that this condition does not represent a significant terrain flight problem and the integration of the CWS in the UH-1H is complete.

OH-58A Integration

During the adjustment flight in the 50-Hz mode, an N1 sweep was conducted from 99% to 65% and airspeed was varied from 0 to 120 KIAS. At N1 speeds below 75%, a magnetic field was generated which resulted in CWS outputs as high as 6 volts, well in excess of any reasonable threshold settings. N1 speeds of 75% and below are not expected during normal terrain flight modes or during takeoff and landing; however, during expedited descents or engine failure, N1 may enter this range, resulting in a CWS alert and possible pilot reaction to a threat which does not exist. CWS alerts also occurred when the position lights were turned on and off, and when landing lights were turned on.

During subsequent adjustment flights, the CWS alerted in minimum and maximum sensitivity on a random and intermittent basis. There was no correlation between CWS alerts and flight mode or condition. CWS alerts during flight at N1 speeds below 75%, during landing and position light actuation, and on a random and intermittent basis throughout the flight envelope will result in an unacceptably high false alert rate. Therefore, the integration of the CWS on the OH-58A is incomplete and will require additional effort.

CH-47D Integration

The contractor was unable to determine a suitable location for the CWS sensor unit from the CH-47D aircraft mapping work accomplished to date. Therefore, the integration of the CWS on the CH-47D is incomplete and requires additional effort.

ENGINEERING FLIGHT EVALUATION

The objective of the engineering flight evaluation was to determine the CWS's capability to detect and provide effective warning to the pilot of energized power line hazards in the terrain and otherwise low-level flight environments. This evaluation consisted of flight tests and limited pilot evaluations. The flight tests consisted of a warning time test and a bearing accuracy test designed to provide limited quantitative information on system performance. The pilot evaluations were designed to obtain qualitative information on CWS performance.

Flight Tests

Warning Time Test. The objective of this test was to document CWS warning times on a large set of power lines. Each aircraft was flown toward the power lines at the James River bridge at 350 feet mean sea level (MSL) and 80 KIAS. A stopwatch was started at the first aural "wires" indication and the time was recorded as the aircraft passed directly over the center of the power line set and again when the display went blank on the other side of the power lines. Runs were conducted with aircraft heading perpendicular to the wires and at 45 degrees either side of the perpendicular. Representative current levels in the cable set used for the evaluation were on the order of 280 to 320 amps per phase. Warning times were on the order of 15 to 20 seconds, and this translates to a range at 80 knots of 2027 to 2702 feet (0.618 to 0.824 kilometer). These times and ranges reflect the warning provided at a particular set of cables on a given day. No attempt was made within this program to quantify (either CONUS or OCONUS) the magnitude of power fluctuations within a given cable set.

It has been observed and confirmed with the electric utilities that current levels in cables sometimes vary greatly with the time of day, season of the year, overall power system load distribution, and possibly other factors. Additionally, the degree of phase balance affects the size of the electromagnetic field generated from a cable set. The higher the degree of balance, the smaller the electromagnetic field and, consequently, the shorter the warning time and range at a given airspeed. Although the warning times were considered adequate under the test day conditions, caution should be used when applying these results to unknown power lines with differing characteristics.

Bearing Accuracy Test. The objective of this test was to confirm that proper relative bearing information was being displayed to the pilot. The aircraft were flown to a position where the display was illuminated and hovered at 350 feet MSL. A 360-degree pedal turn was conducted and the bearing display checked for accuracy as the aircraft heading passed through each 45 degrees of bearing relative to the power lines. The bearing information for the AH-1F and the UH-1H was correct within 10 degrees and the accuracy was considered to be adequate. For the AH-64A, the relative bearing did not change from the straight-ahead indication to the 45-degree indication until aircraft heading was approximately 80 degrees from the perpendicular. An alteration was made to the CWS sensor unit to correct this problem, but was not tested due to aircraft maintenance problems.

The bearing information on the AH-64A was later checked in Germany and found to be correct. Therefore, the CWS bearing information is correct on the UH-1H, AH-1F, and AH-64A installations.

Pilot Evaluation

The primary objective of this evaluation was to obtain pilot opinions of CWS effectiveness in detecting and warning of energized power line hazards in the terrain flight environment. Four pilots participated in the evaluation and flights lasted approximately 1 hour each. Three evaluations were conducted using the UH-1H and one using the AH-1F. Each pilot was briefed on the use, capabilities, and limitations of the CWS, as well as on the conduct of the

evaluation. The predetermined terrain flight course used for the evaluation consisted of a low-level portion flown at 80 KIAS and approximately 100 feet above highest obstacle (AHO), and a nap of the earth (NOE) portion flown at approximately 40 KIAS and 10 to 20 feet AHO. All flights were conducted under day visual meteorological conditions.

The project test pilot flew the aircraft to ensure consistent course following, and the evaluation pilot was asked to simulate the scan technique he would normally use if he were flying the aircraft and to comment on the information provided by the CWS. Each pilot was flown around the terrain flight course under the above conditions at least once and then afforded the opportunity to refly all or any part of the course as desired. Pilot comments were collected during and after the flight. All evaluation pilots felt that the CWS possibly had the potential to prevent some wire strikes and usually provided sufficient time to execute a wire avoidance maneuver. Despite the generally positive nature of their comments, the pilots did express the following concerns about the system's limitations and use:

1. The system provided no alert on cables carrying little or no current and insufficient reaction time on some cables. The concern was that pilots may become overreliant on the CWS and reduce their vigilance, resulting in wire strikes that may have been avoided had the pilots maintained normal concern with wire avoidance.

2. Because the CWS is sensitive to all cables which carry sufficient current, it often alerted on cables that were down in the trees or otherwise not a potential threat to the aircrew. One concern was that these alerts may be distracting, especially at night, and may cause the pilot to continuously react where no threat exists. A second concern was that pilots would begin to ignore or disable the system if these alerts were perceived to be "false alarms."

3. One pilot expressed a concern that the limited nature of this test did not permit sufficient CWS experience from which to make a valid assessment of the system's capabilities. He recommended that further evaluations permit pilots to operate the system over a longer period of time under both day and night conditions.

Based on the results of the integration effort and limited pilot evaluation, the decision was made to conduct a more comprehensive evaluation in Germany and Korea.

OCONUS FLIGHT EVALUATION

The objective of the OCONUS flight evaluation was to qualitatively assess the ability of the PROAV CWS to assist helicopter crews in avoiding wire hazards in the terrain flight environment. The evaluation was conducted in a tactical environment in Germany using five AH-64A helicopters and in Korea using three AH-1F and two UH-1H helicopters.

EVALUATION ACTIVITY

After CWS installations, which followed the same procedures as the CONUS installations, functional check-flight(s) were performed that generally repeated the integration outlined in Steps 3 through 5, pages 8 and 9. The PROAV technical representative was permitted to readjust CWS sensor gains and thresholds to compensate for differences in the wire environment from that of the Fort Eustis, Virginia, vicinity. Immediately prior to the start of the evaluations, flight crews were thoroughly briefed on the operation and limitations of the CWS in the presence of the PROAV technical representative.

The systems were then operated during normal training missions on a noninterference basis for the ensuing 2-month period at each location. A Government technical representative from AATD remained in the vicinity in each respective country for the duration of each evaluation. His function was to monitor the accumulation of flight hours on each CWS-equipped aircraft, answer any routine questions from the pilots, and provide any CWS-related maintenance assistance as required to the aviation units involved. Table 2 presents the number of pilots participating in the test and the total flight hours in each aircraft.

TABLE 2. CWS OCONUS FIELD EVALUATION - FLIGHT HOUR/PILOT SUMMARY

CATEGORY	AH-64	AH-1F	UH-1H	TOTALS
	(GERMANY)	(KOREA)		
DAY	32.0	73.7	48.0	153.7
NIGHT (UNAIDED)	3.6	11.4	4.8	19.8
NIGHT (NVG/PNVS)	19.8	11.9	1.8	33.5
TOTALS	55.4	97.0	54.6	207.0 HR
NUMBER OF PILOTS	14	15	11	40 PILOTS

DATA ANALYSIS

At the conclusion of the evaluation, the 16-part questionnaire presented in Appendix A was administered (by AATD's experimental test pilot) to each participating pilot. The questionnaire was conducted as an interview to assure that the pilots understood the intent of each question and that the pilots' intended answers were obtained. The questions can be separated into three subject areas: CWS performance and effectiveness (Questions 8, 9, 11, and 12), pilot confidence (Questions 13 and 15), and man-machine interface (MMI) issues (all remaining questions). The responses to the MMI questions are of interest if and when the CWS demonstrates a level of performance that engenders sufficient pilot confidence for it to be considered a viable safety system. Since the MMI issues were clearly secondary to the stated objective, no detailed analysis of these questions was attempted. However, a cursory look at these responses revealed no monumental MMI issues that could not be readily solved.

Initial review of the questionnaires revealed that 7 of 11 UH-1 pilots had accumulated no flight time in the terrain flight environment. Because the CWS was being evaluated as an aid to terrain flight, those 7 pilots were eliminated from the data base. The results of all questions for the 33 remaining pilots are presented in histogram format in Appendix B. The data were next examined in the following three ways in an attempt to assess the value of the CWS:

1. Separate data sorts were run for pilots whose CWS time included night flight versus those flying in daytime only. It was reasoned that pilots with night experience might have felt the CWS to be of more/less value than others. This data is presented in Appendixes C (night experience) and D (daytime only).

2. Responses of pilots having less than 500 hours total flight time were examined against the responses of more experienced pilots to determine if younger pilots were more/less accepting of the CWS than older pilots. This data is presented in Appendixes E (less than 500 hours) and F (over 500 hours).

3. Responses of pilots were examined according to how many total flight hours the individual had accumulated with the CWS in this evaluation. The rationale was that pilots may like the CWS more/less according to the amount of time they accumulate with the system.

A review of the answers to key questions using the above data sorts revealed a wide range of responses from the various pilot populations. No specific conclusions, however, could be drawn based on this data and no significant findings were rendered with respect to the performance and effectiveness of the CWS.

ANALYSIS OF KEY QUESTIONS

The four questions discussed below, concerning performance and effectiveness, and pilot confidence, provide the key information necessary for a detailed assessment of the value of the CWS to the pilot operating in the terrain flight environment. An initial review of the discreet responses and comments to these questions revealed a wide range of opinion on what pilots

considered an acceptable level of performance. For instance, Figure 2 shows the responses to question 11. Some pilots marking "very reliable" estimated a lower percentage of wire detections than other pilots marking only "reliable." Therefore, it was judged that there could be little significance attached to the difference between these two answers. As a result, the "reliable" and "very reliable" responses were grouped into a single bar labeled "reliable." The same was done with the unfavorable side of the response scale, resulting in the three-bar histograms used in the remainder of this discussion.

The questions and their respective responses below were analyzed as a whole in arriving at the conclusions in this report; therefore, they must be considered as a whole and not individually in order to fully appreciate the overall opinions of the pilots in the various CONUS and OCONUS locations. The analysis of these questions provides the major basis for the conclusions contained in this report.

Question 11

Was the CWS a reliable indicator that wires were in the vicinity (that is, when a wire is present, did the CWS provide an indication)?

Figure 3 is the pilot response summary to question 11. This question deals only with the issue of the CWS's ability to detect the presence of wires; it does not address sufficient reaction time or false alarms.

The responses from Germany clearly indicate that the CWS was not a reliable indicator of the presence of wires in that environment. During initial system checkout flights in Germany, the CWS's detection performance was less than expected. Hand-held magnetometer readings taken on wires within the training area indicated that, for whatever reason, the power lines in Germany were not carrying very high current levels. Because detection performance is directly linked to current level, the poor detection performance indicated by Figure 3 is probably a result of the low current levels. It is concluded that the CWS is not a reliable detector of wires in the German wire environment.

The responses from Korea indicate that 47% of the pilots felt that the system was a reliable indicator of wires and 16% felt that the system was unreliable. Because less than half of the pilots believed the CWS was reliable, the number of pilots (37%) marking borderline on this question becomes significant. Those marking borderline had at least some doubts about the CWS's ability to consistently detect wires. It is possible that pilot responses to this question relate to differences in the overall current levels or wire density found in Korea versus those in Germany. While it was concluded that current levels in Germany were generally lower than in Korea, the wire density in Korea was found to vary dramatically depending on location. Areas around K-16 (just south of Seoul) were as dense, and in some areas more dense, than in Germany. In consideration of the above, it is concluded that the CWS is not a consistently reliable detector of wires in the Korean wire environment.

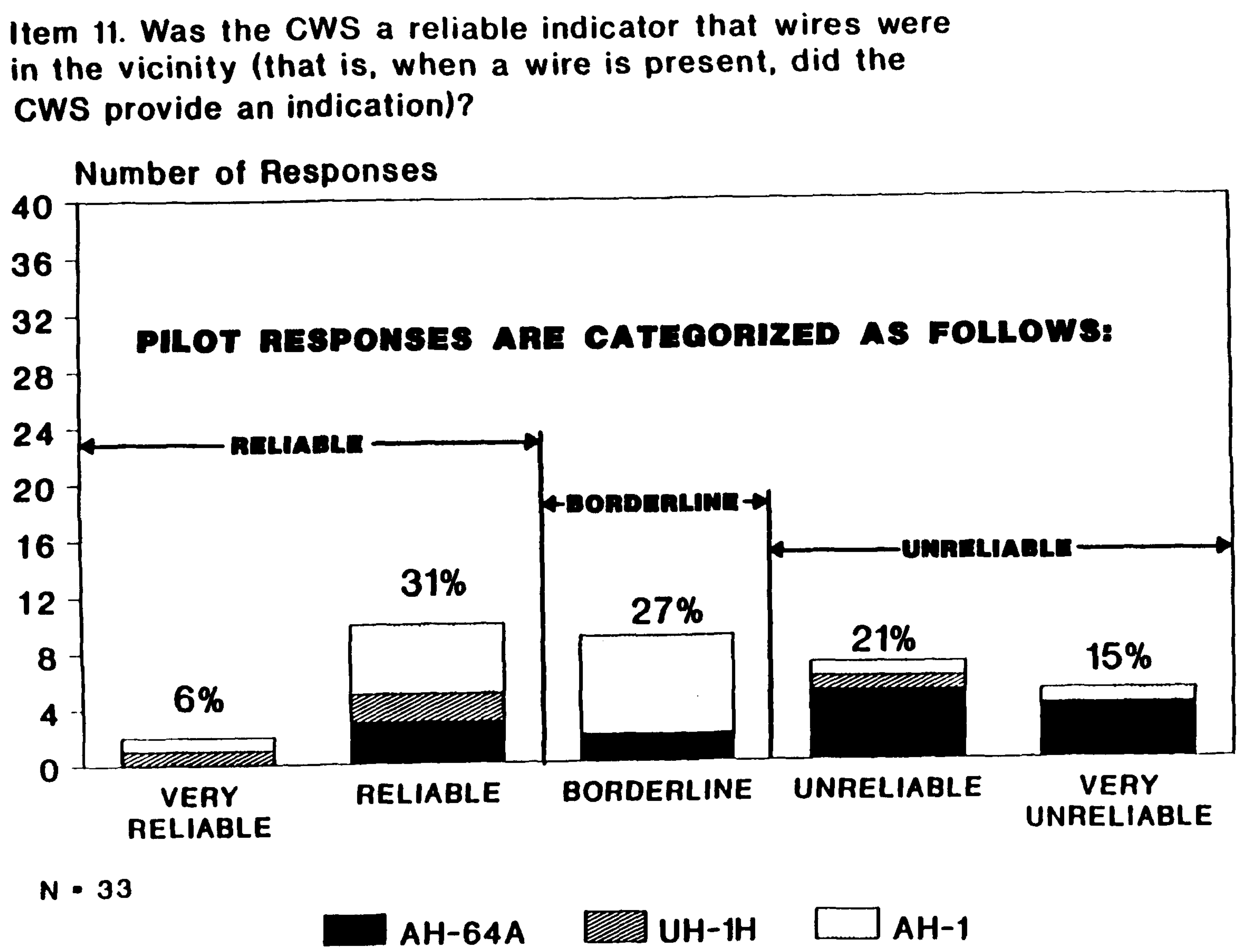

Figure 2. Example of pilot response selections to survey question on reliability.

WAS THE CWS A <u>RELIABLE</u> INDICATOR THAT WIRES WERE IN THE VICINITY?

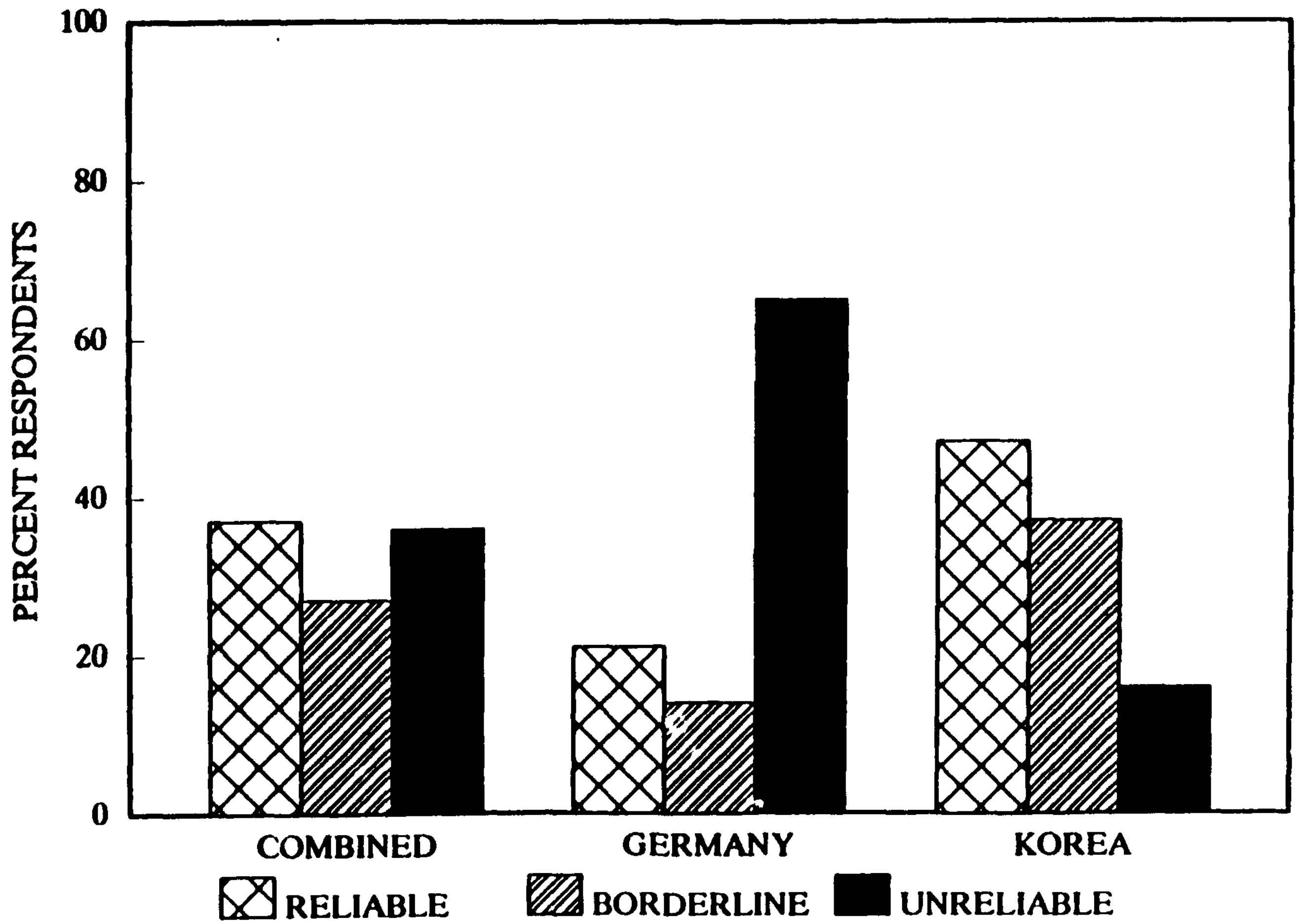

Figure 3. Pilot response summary to key question on reliability.

Question 12

Evaluate the false alarm rate of the CWS (a false alarm is when the CWS indicates wires are present, but no wires are in the vicinity).

Figure 4 is the pilot response summary to question 12.

The number of borderline (36%) and unacceptable (29%) responses from pilots in Germany indicates that there was some level of concern with false alarms. There is no clear explanation for the perceived false alarms, although in at least one location in the training area there was an underground cable that may have been the source of some of the alarms. There may also have been some cases when a wire was actually present that the pilot did not or could not locate. It should also be noted that during initial checkout flights in Germany, stabilator-induced false alarms were noted in 3 of 5 aircraft despite the modifications developed during the integration phase. It was found that flight with the Automatic Stabilator ac and dc circuit breakers pulled out eliminated the problem. With the concurrence of unit maintenance personnel, an entry was made in the aircraft logbook restricting those aircraft to flight with the Automatic Stabilator circuit breakers pulled out. This was a temporary solution to complete the evaluation; however, further investigations would be required for a completely successful integration in the AH-64A. Since false alarms were perceived as a problem by AH-64 pilots in Germany, further work is required to fully integrate the CWS into the AH-64A.

The response to the false alarm question in Korea indicates that there was not a problem with false alarms as defined in the questionnaire. That is, when the CWS alerted, there was always a wire in the vicinity. There was some concern, however, with alerts on wires that were down in the trees or otherwise not perceived as threats. Approximately one-third of the pilots in Korea commented that the CWS alerted on wires not perceived as threats. These alerts can be distracting, and if they occur often, will reduce the pilot's tendency to immediately respond to CWS alerts. By the strict definition of a false alarm, the false alarm rate is acceptable in the Korean wire environment; however, continual alerts to nonthreat wires will increase the pilot's workload under complex/high gain flight conditions.

Question 8

In general, did CWS warn you of the presence of wires in sufficient time to successfully perform an avoidance maneuver?

Figure 5 is the pilot response summary to question 8. In cases where the wire was a threat, pilots noted that they always saw the wires prior to the CWS, and therefore, passed above the wires and were not required to perform an avoidance maneuver in response to a CWS alert. This is not an unexpected comment, given the level of concern with wire avoidance in most aviation units.

In Germany, the majority (62%) of the pilots indicated that the CWS did not provide sufficient reaction time, while only 15% did. This result was expected based on what was learned about

EVALUATE THE FALSE ALARM RATE OF THE CWS (FALSE ALARM DEFINED AS: THE CWS INDICATES WIRES ARE PRESENT, BUT NO WIRES ARE IN THE VICINITY)

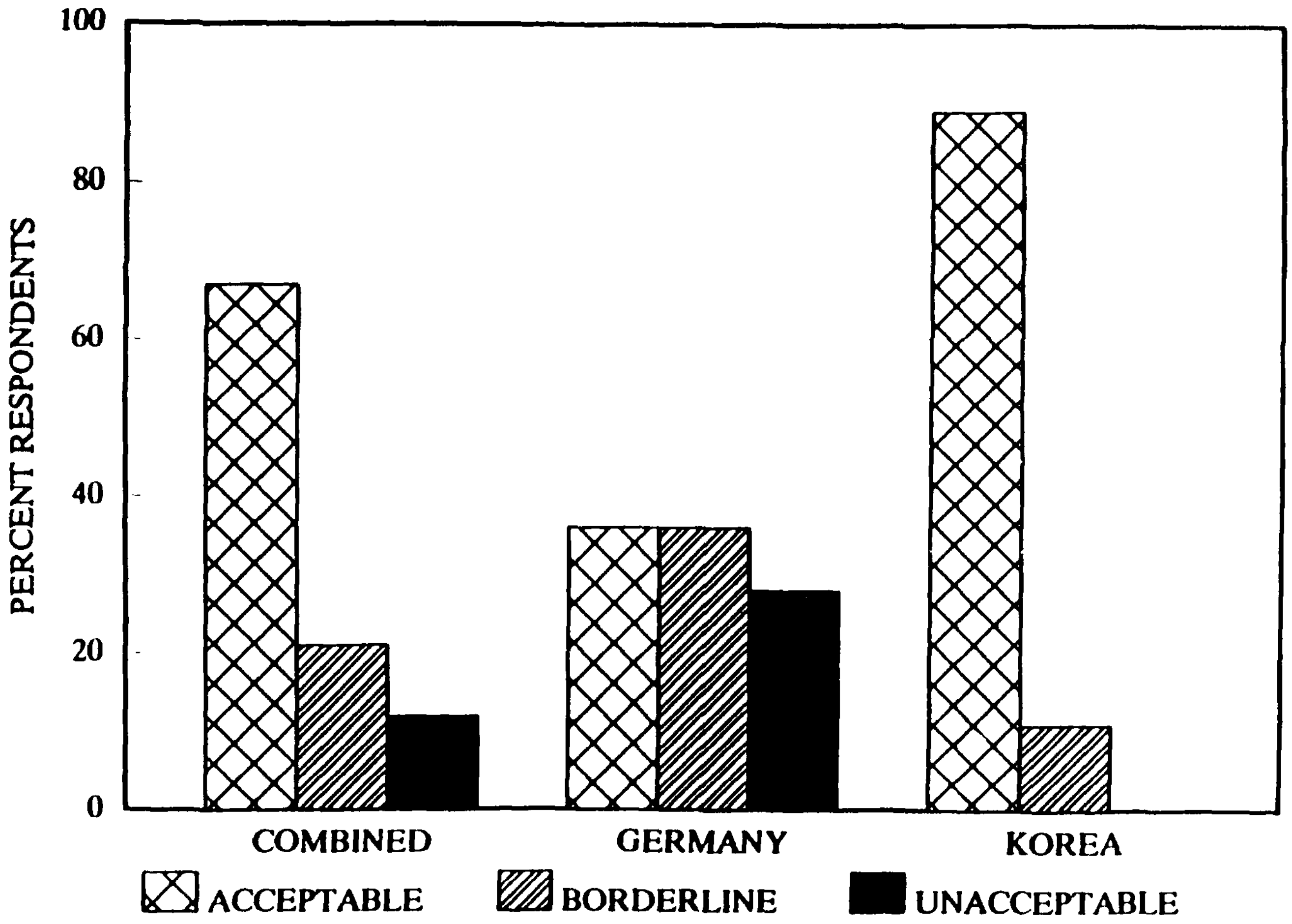

Figure 4. Pilot response summary to key question on false alarms.

IN GENERAL, DID CWS WARN YOU OF THE PRESENCE OF WIRES IN SUFFICIENT TIME TO SUCCESSFULLY PERFORM AN AVOIDANCE MANEUVER?

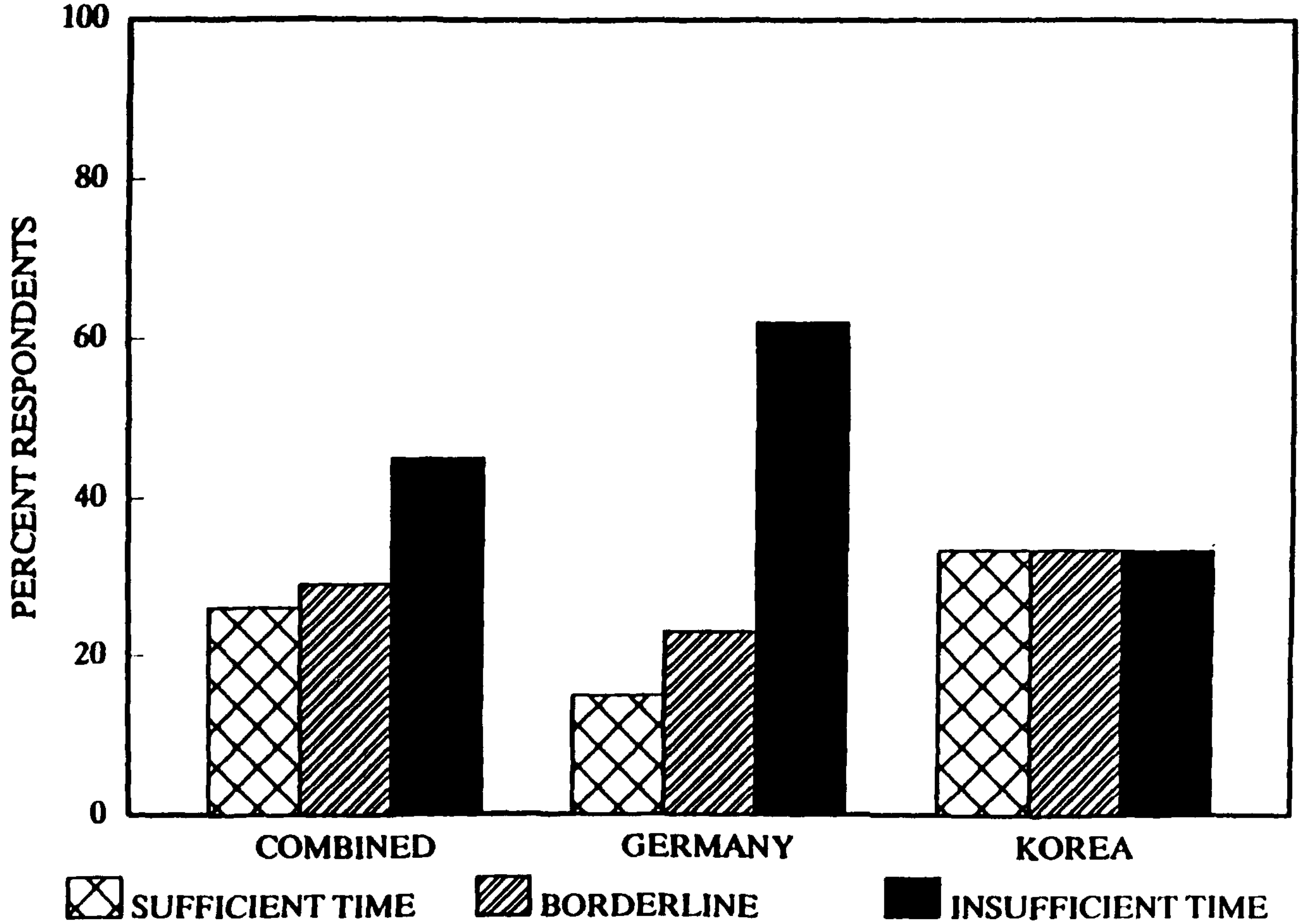

Figure 5. Pilot response summary to key question on reaction time.

the low current levels in Germany during the initial system checkout procedure. It is concluded that the CWS does not consistently provide sufficient time for pilots to perform an avoidance maneuver in the German wire environment.

In Korea, pilot opinion was mixed, with a one-third split of those finding sufficient, insufficient, and borderline reaction times. This split shows that the CWS performed differently for different groups of pilots. The spectrum of responses on this subject indicates that the CWS did not consistently provide sufficient reaction time for the pilots evaluating the system.

Question 15

Overall, do you believe that CWS will help aviators avoid wire strikes?

Figure 6 is the pilot response summary to question 15. This question was designed to determine the level of confidence pilots had in the capabilities of the CWS to assist with wire avoidance.

The majority (71%) of the pilots in Germany did not believe that the CWS would help aviators avoid wire strikes. This low confidence level follows from the system performance and effectiveness problems examined in the previous three questions. In summary, in the German wire environment the CWS was not a reliable detector of wires, there was a perceived problem with false alarms, and the system did not consistently provide pilots with sufficient time to perform an avoidance maneuver. Pilot confidence in CWS capabilities in Germany is low.

Less than half (47%) of the pilots in Korea felt that the CWS would help aviators avoid wire strikes. This marginal to low confidence level reflects the inconsistent performance of the CWS as discussed in the previous three questions. In summary, in the Korean wire environment the CWS was not a consistently reliable detector of wires; there was not a problem with false alarms as defined herein, though there was some concern with alerts on nonthreat wires; and the system did not consistently provide pilots with sufficient time to perform an avoidance maneuver. Pilot confidence in the CWS capabilities is marginal to low.

OVERALL, DO YOU BELIEVE THAT CWS WILL HELP AVIATORS AVOID WIRE STRIKES?

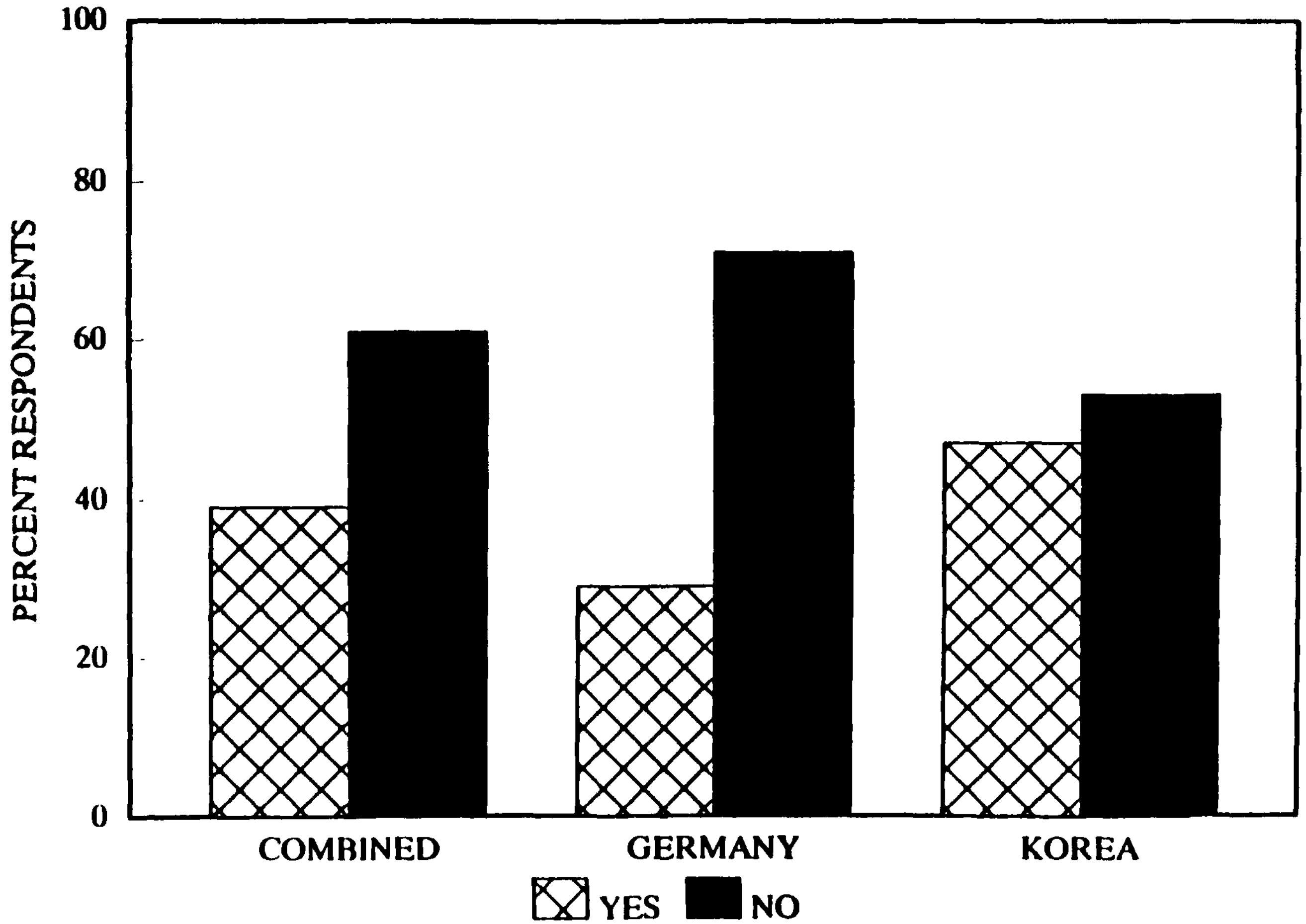

Figure 6. Pilot response summary to key question on pilot confidence.

CONCLUSIONS

GENERAL

The PROAV CWS is not consistent in its ability to detect wires and provide sufficient reaction time for avoidance. As a result, pilot confidence in the capabilities of the CWS is marginal to low. This conclusion is reinforced by the pilot responses to two survey questions - one relating to CWS performance (question 9) and one to pilot confidence (question 13). For question 9, of the 33 pilots in the data base, 97% (all but one) reported at least one case where the CWS did not warn them in sufficient time to perform an avoidance maneuver. For question 13, a majority (55%) disagreed with the statement that the CWS will help to substantially reduce helicopter wire strike accidents. Although the CWS sometimes indicates that wires are in the vicinity and sometimes provides sufficient time for pilots to perform an avoidance maneuver, its performance is not consistent enough to be an effective aid to wire avoidance in the low altitude and terrain flight environments. In addition, significant aircraft integration issues remain unresolved for several U.S. Army fleet aircraft.

SPECIFIC

1. The integration of the CWS on the AH-64A is complete (page 10).

2. The integration of the CWS on the UH-60A is incomplete and will require additional effort (page 11).

3. The integration of the CWS on the AH-1F is complete (page 11).

4. The integration of the CWS on the UH-1H is complete (page 12).

5. The integration of the CWS on the OH-58A is incomplete and will require additional effort (page 12).

6. The integration of the CWS on the CH-47D is incomplete and will require additional effort (page 12).

7. The CWS is not a reliable detector of wires in the German wire environment (page 17).

8. The CWS is not a consistently reliable detector of wires in the Korean wire environment (page 17).

9. False alarms were perceived as a problem by AH-64 pilots in Germany, and further work may be required to fully integrate the CWS into the AH-64 (page 20).

10. By the strict definition of a false alarm, the false alarm rate is acceptable in the Korean wire environment (page 20).

11. The CWS does not consistently provide sufficient time for pilots to perform an avoidance maneuver in the German wire environment (page 20).

12. The CWS does not consistently provide sufficient time for pilots to perform an avoidance maneuver in the Korean wire environment (page 23).

13. Pilot confidence in the capabilities of the CWS in Germany is low (page 23).

14. Pilot confidence in the capabilities of the CWS in Korea is marginal to low (page 23).

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16. Airworthiness Release for UH-1H Helicopter with PROAV Cable Warning System (CWS) Installed, USAAVSCOM, St. Louis, Missouri, 17 December 1991.

APPENDIX A
FIELD EVALUATION PLAN FOR THE PROAV CABLE WARNING SYSTEM

INTRODUCTION NOVEMBER 1991

1.1 BACKGROUND
The PROAV Cable Warning System (CWS) was tested by the Communications and Electronics Command (CECOM) at Ft. Rucker, Alabama, during July 1989. Testing was conducted using a modified AH-1S aircraft equipped with the CWS. The results of the evaluation were inconclusive. The CWS was also installeo on an OH-58 aircraft in January, 1990 at Ft. Eustis, Virginia, for further evaluation by the Aviation Applied Technology Directorate (AATD), AVSCOM. Technical difficulties were encountered during the aircraft integration phase, precluding further testing. AATD was tasked by AVSCOM in January, 1991, to integrate and evaluate the CWS on the AH-1, UH-1, OH-58, AH-64, UH-60, and CH-47D aircraft, with a follow-on field evaluation to take place in Germany and Korea if the system demonstrated potential. Successful integration was achieved on the AH-64, AH-1, and UH-1 aircraft. A limited qualitative pilot evaluation indicated that the system demonstrated the potential to assist with wire strike avoidance. On 19 August 1991, The U.S. Army Materiel Command (AMC) directed AVSCOM to proceed with a field evaluation of the CWS in Europe and Korea.

1.2 EVALUATION OBJECTIVE
The objective of this evaluation is to qualitatively assess the ability of the PROAV CWS to assist helicopter crews in avoiding wire hazards in the terrain flight environment.

1.3 DESCRIPTION OF EQUIPMENT
The PROAV CWS is a 3-axis magnetometer designed to detect the magnetic field surrounding electrical power transmission lines. The system is designed to detect only those lines which are carrying electrical current, and the detection distance will vary proportionally to the magnitude of the current in the lines. The system consists of a sensor unit, a cockpit display, and an automatic voice alerting unit. The sensor unit and automatic voice alerting system are usually mounted together in the tailboom section as far away from aircraft generated electromagnetic noise as possible. The system is designed to provide an aural "Wires, Wires, Wires" warning to the flight crew through the intercom system (ICS) when an magnetic field is detected. At the same time, the cockpit display will illuminate lights in a pattern designed to show the relative bearing to the wires. A more detailed description of the CWS and it's installation configuration for specific aircraft can be found in the AATD airworthiness substantiation documents.

1.4 EVALUATION SCOPE
The evaluations will be conducted at selected Army installations in Europe and Korea. The number and type of aircraft selected for use in the evaluation will be determined by AMC in conjunction with U.S. Army Europe (USAREUR) or Eighth U.S. Army, Korea (EUSA), as appropriate. It is currently projected that 5 CWS units will be available for evaluation in each theater. AATD will furnish the hardware and technical assistance required to install the CWS in the test aircraft. Manpower assistance and the use of common tools during the installation of the CWS will

be requested from the units selected to participate in the evaluation. Additional technical expertise relating to CWS calibration and operation will be provided by PROAV International personnel under contract to AATD, if required. The systems will remain on the aircraft for approximately two months. The selected aviation units will be requested to use the system in the terrain flight environment and provide feedback on CWS performance via a post-evaluation questionnaire, appendix B. A minimum of 6 pilot evaluations (10 desired) is required to provide sufficient information from which to make an assessment. Flights should be conducted under day and night conditions, and with night vision systems (NVS), as appropriate. The proportion of day to night flying should reflect the units normal training profile. Efforts will be made to select units for the evaluation that will fly the CWS in the terrain flight environment under night conditions. At the conclusion of the evaluation, AATD will provide the support necessary to return the aircraft to standard configuration. All test aircraft will be standard U.S. Army aircraft and will be operated in accordance with (IAW) the appropriate aircraft operator's manual, appendix A references 1-3. Terrain flight will be conducted IAW the appropriate Aircrew Training Manuals, appendix A references 4-6, and applicable unit Standard Operating Procedures (SOP's). Test management procedures will be conducted IAW the test operations plan, appendix C, test safety is discussed in appendix D.

DETAILS OF TEST

2.1 GENERAL

This evaluation is primarily a qualitative assessment of the ability of the CWS to assist flight crews in avoiding wire hazards in the terrain flight environment. The evaluation will be conducted in three phases. Phase I will consist of the CWS installation and check-out, and flight crew instruction on the use, capabilities, and limitations of the system. The flight crew instruction will not take place until just prior to the beginning of phase II. Phase II will consist of the flight evaluations and completion of the post-evaluation questionnaires. Phase III will consist of the removal of the CWS from the units aircraft, and compilation and analysis of the data. An outbrief of the preliminary data assessment will be provided to the evaluation unit if desired. Although no detailed Reliability, Availability, Maintainability (RAM) data will be collected, flight and maintenance crews should report suspected failures of the system to the on-site test manager. In addition, those personnel assisting with the installation of the CWS will be requested to provide comments regarding installation locations or procedures.

2.2 PHASE I: INSTALLATION, SYSTEM CHECK-OUT, AND PILOT INSTRUCTION

2.2.1 Installation

If available, appropriate personnel from the unit maintenance organization will observe/assist with the installation and adjustment of the CWS IAW the AATD installation procedures. Prior to the installation of the sensor unit, the contractor will set CWS gains and thresholds to the levels determined during the AATD integration effort. Once set, these gains and thresholds will not be adjusted without the approval of the evaluation director. Comments from unit personnel concerning any aspect of the system installation or adjustment procedure will be solicited and documented.

2.2.2 System Check-out

Once installed and operational, the CWS will be checked for aircraft electromagnetic interference and compatibility (EMI/EMC) both on the ground and in flight. The objective of the EMI/EMC check is to determine if the CWS affects the operation of aircraft systems. The EMI/EMC check will consist of the on/off cycling and operation of all possible aircraft systems. Those systems which can not be cycled safely in flight will be checked only on the ground. At the conclusion of the EMI/EMC checks, the CWS will be calibrated in flight in accordance with the contractor's instructions. Once the CWS has been satisfactorily calibrated, the system will be checked for false alarms and detection performance. The false alarm check will consist of an airspeed sweep from hover to velocity never to exceed (Vne), left and right turns conducted incrementally to 60 degrees angle of bank, and climbs and descents conducted incrementally to maximum power climb and engines coupled autorotation. Detection

performance will be qualitatively evaluated at an isolated cable set, if available. In addition, relative bearing indications will be checked during a hovering pedal turn inside the detection distance to an energized wire set.

2.2.3 Pilot Instruction

The flight crews will be given a briefing prior to the first evaluation flight outlining the use, capabilities, and limitations of the CWS. This briefing will be conducted by a government representative. The crews will also be instructed on the nature of the evaluation, test procedures, safety, and the contents of the post-evaluation questionnaire.

2.3 PHASE II: FLIGHT EVALUATION

The flight evaluation will be conducted in the terrain flight environment (low level, contour, nap of the earth <NOE>) under day and night conditions. Each evaluation pilot will be asked to fly a predetermined terrain flight course at least once to provide a baseline for the final data assessment. This course will be designed to place the system under a variety of cable situations. The crews will also be free to use the system during all appropriate missions throughout the evaluation period. It is desired that all evaluation pilots gain as much experience with the system as possible to provide a broad basis for their comments and evaluation. Evaluation crews will be asked to keep notes on their experience and impressions of the system using a post-flight data card (appendix E). At the conclusion of the evaluation period, each pilot will complete the post-evaluation questionnaire presented in appendix B. This questionnaire will be completed by each pilot only once and should be filled out when the pilot has completed his final flight with the system. If possible, the on-site test manager will work through the questionnaire with each pilot to ensure that all comments are understood.

2.4 PHASE III: DATA ANALYSIS

At the conclusion of the evaluation phase, the questionnaires will be collected by the on site test manager. AVSCOM, with assistance from the U. S. Army Human Engineering Laboratory (HEL), will review the questionnaires. Discrete responses will be summarized using appropriate descriptive statistics. Qualitative comments will be summarized and tabulated.

APPENDIX A
REFERENCES

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APPENDIX B

CABLE WARNING SYSTEM

FIELD EVALUATION PILOT QUESTIONNAIRE

Name/Rank ____

Date __________________

Unit __________________________

Installation/Location ____

Total Flight Hours ____________

Aircraft used for CWS Evaluation (Circle one)

AH-64 AH-1 UH-1

Flight hours in this model aircraft __________

Flight hours in this CWS evaluation:

Day __________________________

Night (unaided) _____________

Night (NVG/PNVS) ____________

CABLE WARNING SYSTEM
FIELD EVALUATION PILOT QUESTIONNAIRE

PILOT'S NAME______________________

1. Rate the adequacy of the CWS **audio warning** to provide a distinctive cue that wires were in your vicinity.

__ Very Adequate
__ Adequate
__ Borderline
__ Inadequate
__ Very Inadequate

Comments ____

____

____

____

2. Did the CWS audio warning:

a. Interfere with other audio warnings? Yes __ No __

b. Interfere with communications? Yes __ No __

Comments ____

____

____

____

3. Were the CWS display lights easily seen in direct sunlight?

Yes __ No __

If no, could they be easily seen during most daylight conditions?

Yes __ No __

Comments ____

____

____

____

CWS PILOT QUESTIONNAIRE PILOT'S NAME___________________

4. Was the CWS display location usable when wearing NVG/HMD?

Yes __ No __ Didn't Evaluate __

Comments____

____

5. Were the CWS lights NVG/HMD compatible?

Yes __ No __ Didn't Evaluate __

Comments____

____

6. Were the CWS lights adequate for use during night unaided flight?

Yes __ No __ Didn't Evaluate __

Comments____

____

7. Did the CWS provide adequate information for you to determine the relative bearing to the wires?

__ Very Adequate
__ Adequate
__ Borderline
__ Inadequate
__ Very Inadequate

Comments____

____

____

____

____

____

____

____

____

8. In general, did CWS warn you of the presence of wires in sufficient time to successfully perform an avoidance maneuver?

Almost Never 1 2 3 4 5 Almost Always

Comments____

____

____

____

____

____

____

9. Was there ever a case where CWS **did not** warn you in sufficient time to successfully perform an avoidance maneuver?

Yes __ No __

If yes, describe the situation(s)________________________________

____

____

____

10. When CWS indicated that wires were in the vicinity, did you visually verify the presence/location of the wires before starting an evasive maneuver?

__ Always
__ Sometimes
__ Never

Comments____

____

____

____

____

CWS PILOT QUESTIONNAIRE PILOT'S NAME___________________

11. Was the CWS a **reliable** indicator that wires were in the vicinity? (That is, when a wire is present, did the CWS provide an indication?)

__ Very Reliable
__ Reliable
__ Borderline
__ Unreliable
__ Very Unreliable

Comments____

12. Evaluate the false alarm rate of the CWS (a false alarm is when the CWS indicates wires are present, but no wires are in the vicinity).

__ Very Acceptable
__ Acceptable
__ Borderline
__ Unacceptable
__ Very Unacceptable

Comments____

13. The CWS will help to provide a substantial reduction in helicopter wire strike accidents.

__ Quite Agree
__ Moderately Agree
__ Perhaps Agree
__ Perhaps Disagree
__ Moderately Disagree
__ Substantially Disagree

Comments____

14. Is the CWS display lacking any information that is needed to make the system more effective?

Yes __ No __

If yes, what additional information is needed?__________________

CWS PILOT QUESTIONNAIRE PILOT'S NAME__________

15. Overall, do you believe that CWS will help aviators avoid wire strikes?

Yes __ No __

Comments__________

16. Are there additional comments regarding CWS that you wish to make?

Comments__________

APPENDIX C
TEST OPERATIONS PLAN

GENERAL

The Evaluation Director will be responsible for all aspect of the evaluation. Changes to the CWS gain or threshold settings will be made only with the approval of the Evaluation Director or his designated representative. In the event that one of the evaluation personnel listed below is not on site, a member of the unit selected for the evaluation will be designated to monitor the progress of the test and report problems to the Evaluation Director. Changes to the evaluation plan will be made only with the approval of the Director, AATD (AVSCOM).

CONTRACTOR TECHNICAL SUPPORT

The contractor's designated representative will be on site during the test aircraft preparation to assist with installation and system adjustments as requested by AVSCOM. The contractor will be permitted to adjust/confirm the gain and threshold adjustments prior to the final installation of the sensor unit. The contractor will not participate in the debriefing phase of the test. In addition, once the evaluation begins, the contractor's designated representative will not make contact with any member of the evaluating unit without first contacting the designated AVSCOM representative.

TEST AIRCRAFT PREPARATION
The cable warning system will be installed by AATD technical support personnel with the assistance of the contractor's technical representative and designated unit personnel, as appropriate. AVSCOM will provide an airworthiness release for the installation. Once the system has been installed and checked on the ground, a maintenance test flight will be conducted, if appropriate, and an in-flight CWS calibration and function check will be completed. The calibration and function check will be conducted by the contractor's technical representative or the project test pilot, as appropriate.

PILOT INSTRUCTION
A designated government representative will brief the flight crews IAW paragraph 2.2.3 after installation is complete and the evaluation is ready to begin. The contractor's technical representative may be present at the briefing to answer technical questions as directed by the government. The information concerning CWS use, operation, capabilities, and limitations will be prepared and coordinated with the contractor's representative in advance. Questions on CWS operation will be handled by the government representative. If the government representative can not answer a particular question, he will refer the question to the contractor's designated technical representative.

EVALUATION FLIGHT OPERATIONS
Once the CWS installation and pilot instruction briefings have been completed, evaluation flights will begin. The evaluating unit will be responsible for the pre and post mission briefings IAW Army Regulation and local SOP. A post-mission data sheet will be made available for the flight crews for the purpose of recording CWS experience on a flight by flight basis. This sheet should be filled out after each flight to assist the crews in completing the post-evaluation questionnaire at the conclusion of the final flight. The on site test manager will maintain the completed post-mission data sheets on file and will provide them to the evaluation pilots at the conclusion of the evaluation. During the evaluation period, the on site test manager will monitor the routine maintenance of the test aircraft in order to assist with CWS troubleshooting should a problem arise.

TEST SYSTEM MALFUNCTIONS
Flight crews will be asked to report suspected CWS malfunctions to the on site test manager. The test manager should record the failure symptoms and attempt to diagnose and correct the problem using appropriate procedures. The level of troubleshooting and maintenance to be performed by the test manager will be determined prior to test start. If the problem cannot be resolved prior to the next training flight, the circuit breaker should be pulled and banded and the evaluation discontinued on

that particular aircraft until the problem can be resolved. The on site test manager should report suspected malfunctions and actions taken to the evaluation director immediately. If necessary, the evaluation director will contact the contractor's technical representative for assistance in resolving the problem.

APPENDIX D
SAFETY

GENERAL

The highest level of concern for safety will be maintained throughout this evaluation program. Under no circumstances will the need for accomplishing this program override the concern for protecting human and material assets from hazards. Everyone participating in this evaluation will be encouraged to bring to the attention of test managers those issues believed to affect the safe accomplishment of the evaluation objectives. Specific variables affecting safety are discussed below.

EVALUATION SITES

The evaluation will be conducted in approved terrain flight training areas in Germany and Korea. Terrain flight will be conducted IAW the SOP's of the units selected to participate.

AIRCRAFT

An AVSCOM AWR will be provided for the CWS installation in each test aircraft. Unit technical inspection personnel will inspect the completed installation for general condition, security, and safety issues. Concerns will be rectified prior to commencing the evaluation. The aircraft will be maintained by the unit IAW normal maintenance procedures throughout the evaluation with the addition of any periodic qualitative inspections identified in the AVSCOM AWR..

EVALUATION PROCEDURES

The conduct of this evaluation will in no way reduce the unit's need to conduct training IAW their normal regulations, SOP's, and procedures. Aircrews will be thoroughly briefed on the capabilities and limitations of the CWS and will be cautioned against reducing their vigilance in the area of wire avoidance in light of those capabilities and limitations.

APPENDIX E

CABLE WARNING SYSTEM
MISSION PROFILE RECORD

Name______________________________ Date____________________

A/C Tail No _______________

Duration of Flight (Hrs) Day____ Night____ NVG/PNVS____

Mission Altitude ______ ft AGL

Mission Airspeeds ____________ KIAS

Mute Switch Position: On __ Off __

Sensitivity Switch Position: Hi __ Lo __

Was CWS useful during this flight in detecting wires?

Yes __ No __

Comments____

____

____

Did CWS present false alarms during this flight?

Yes __ No __

Comments____

____

____

General comments on CWS____

____

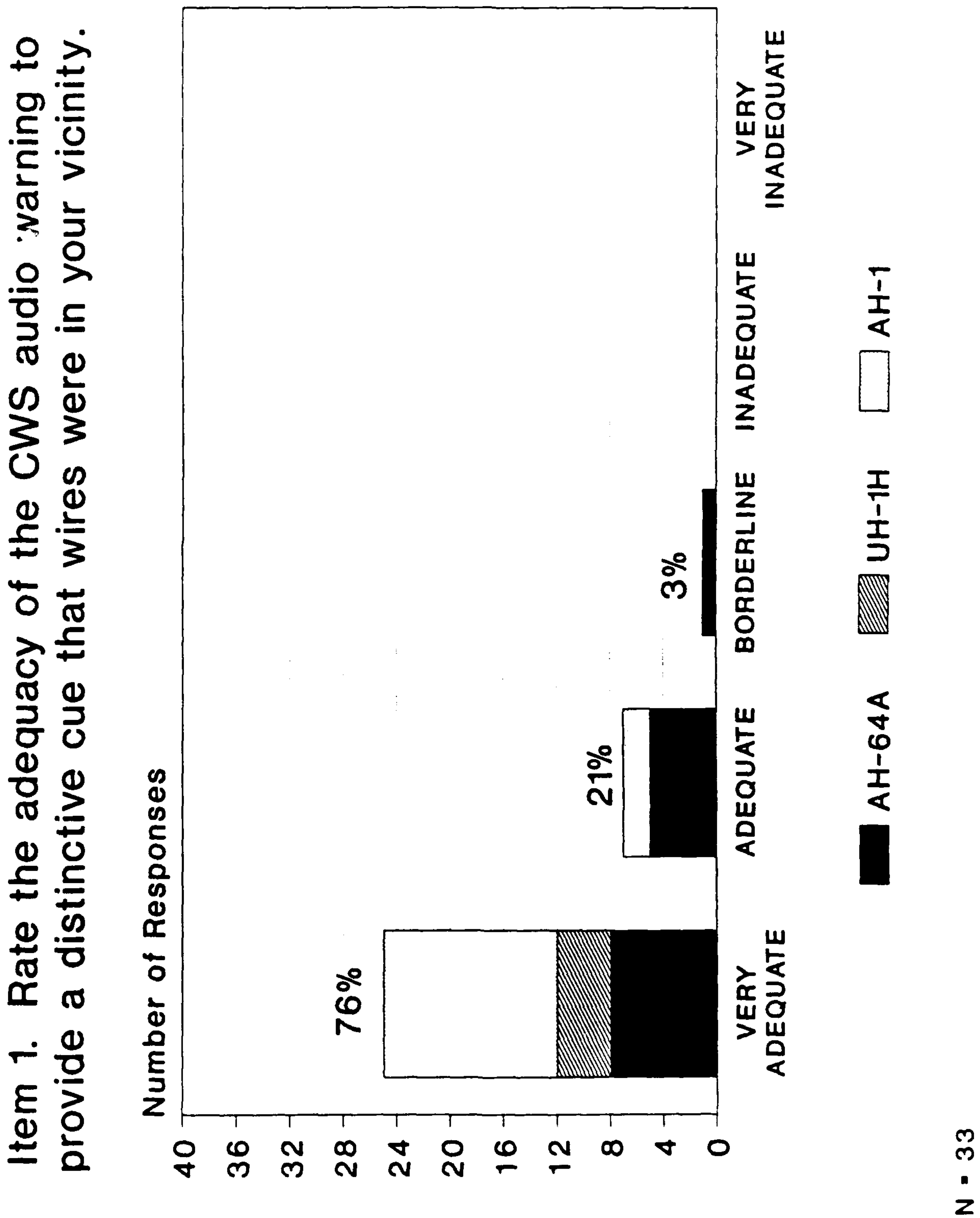
____

____

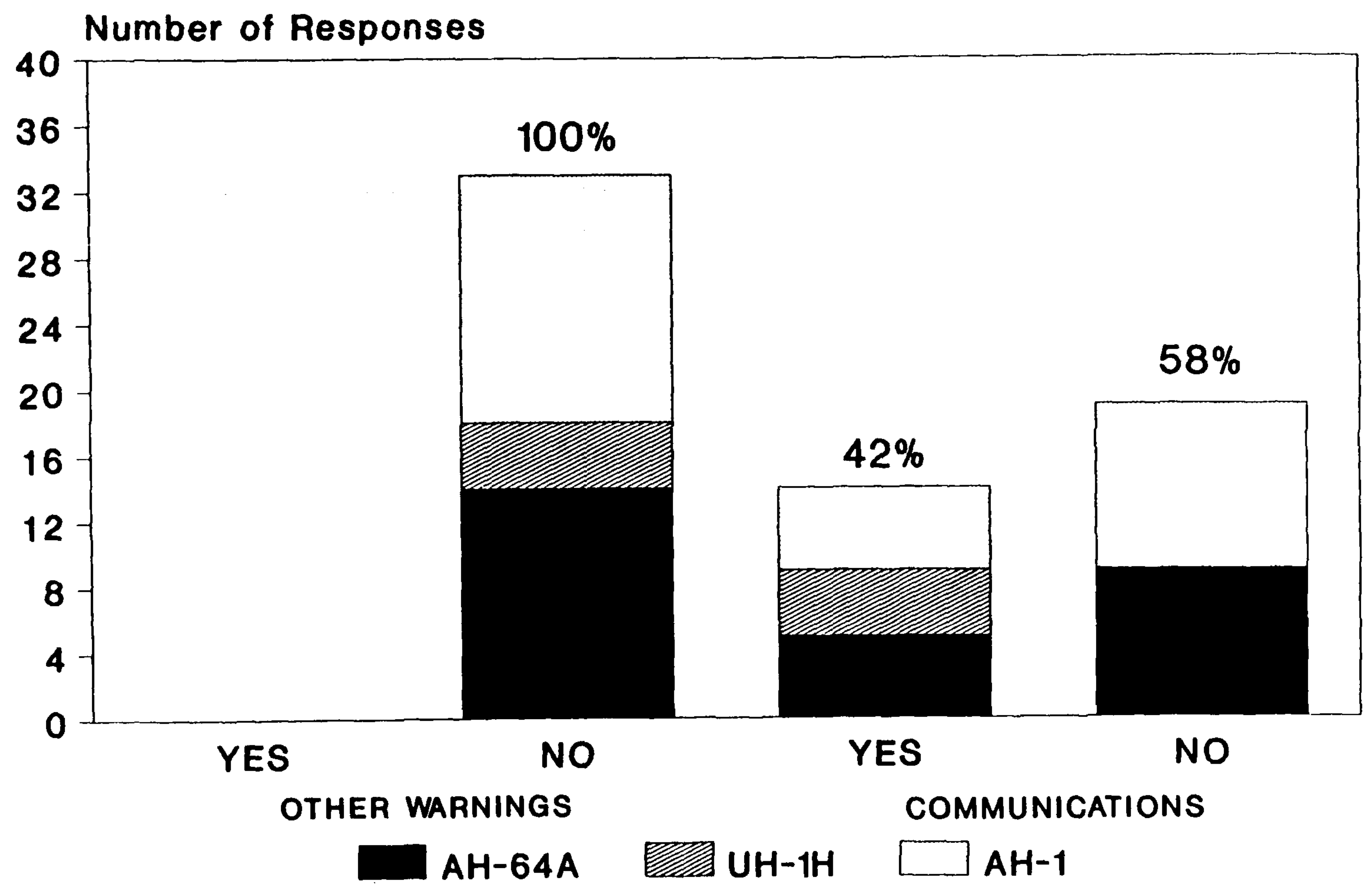
APPENDIX B

OVERALL RESULTS OF CWS QUESTIONNAIRE

(33 Participants)

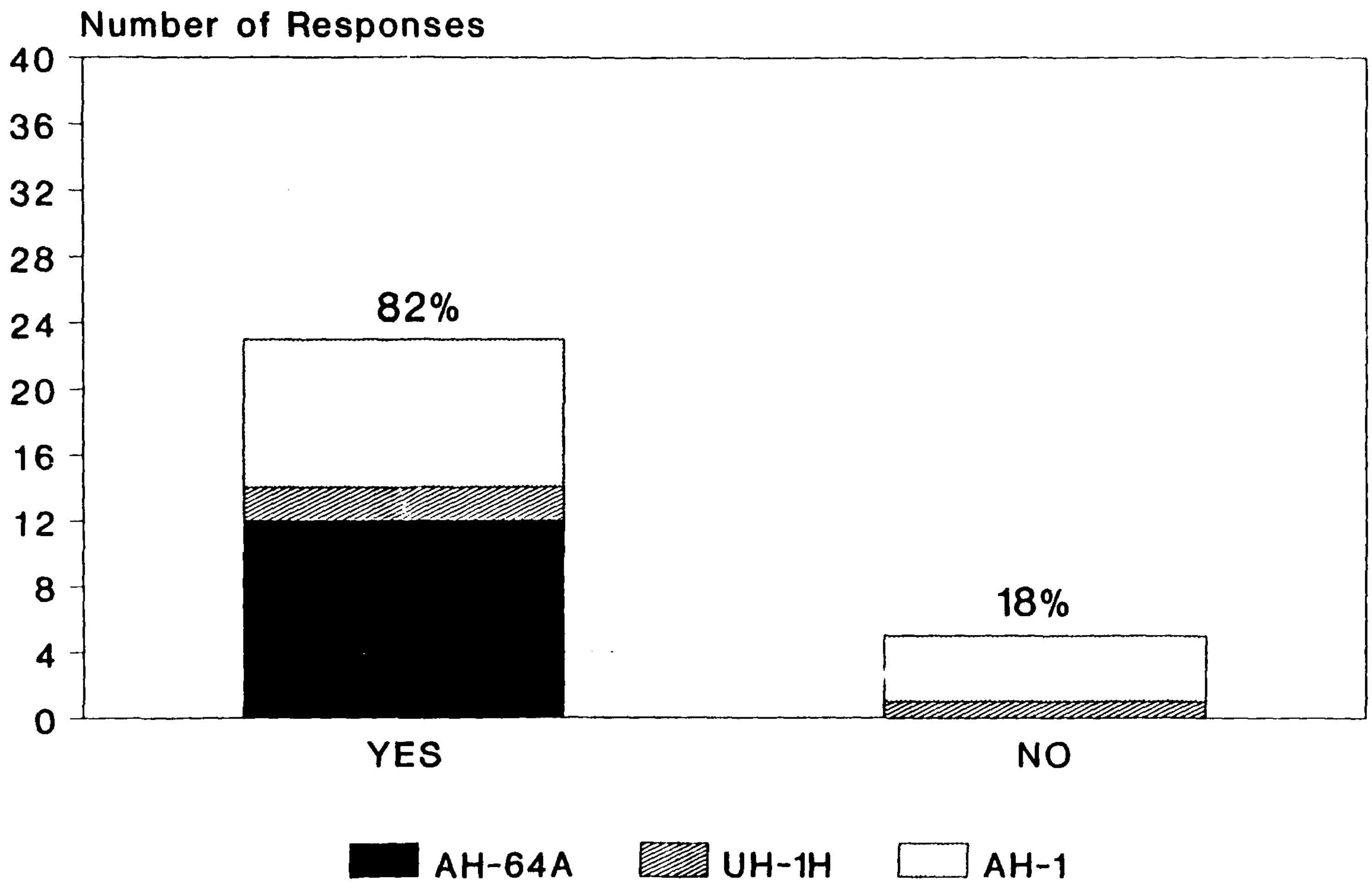


Item 2. Did the CWS audio warnings interfere with other audio warnings or with communications?



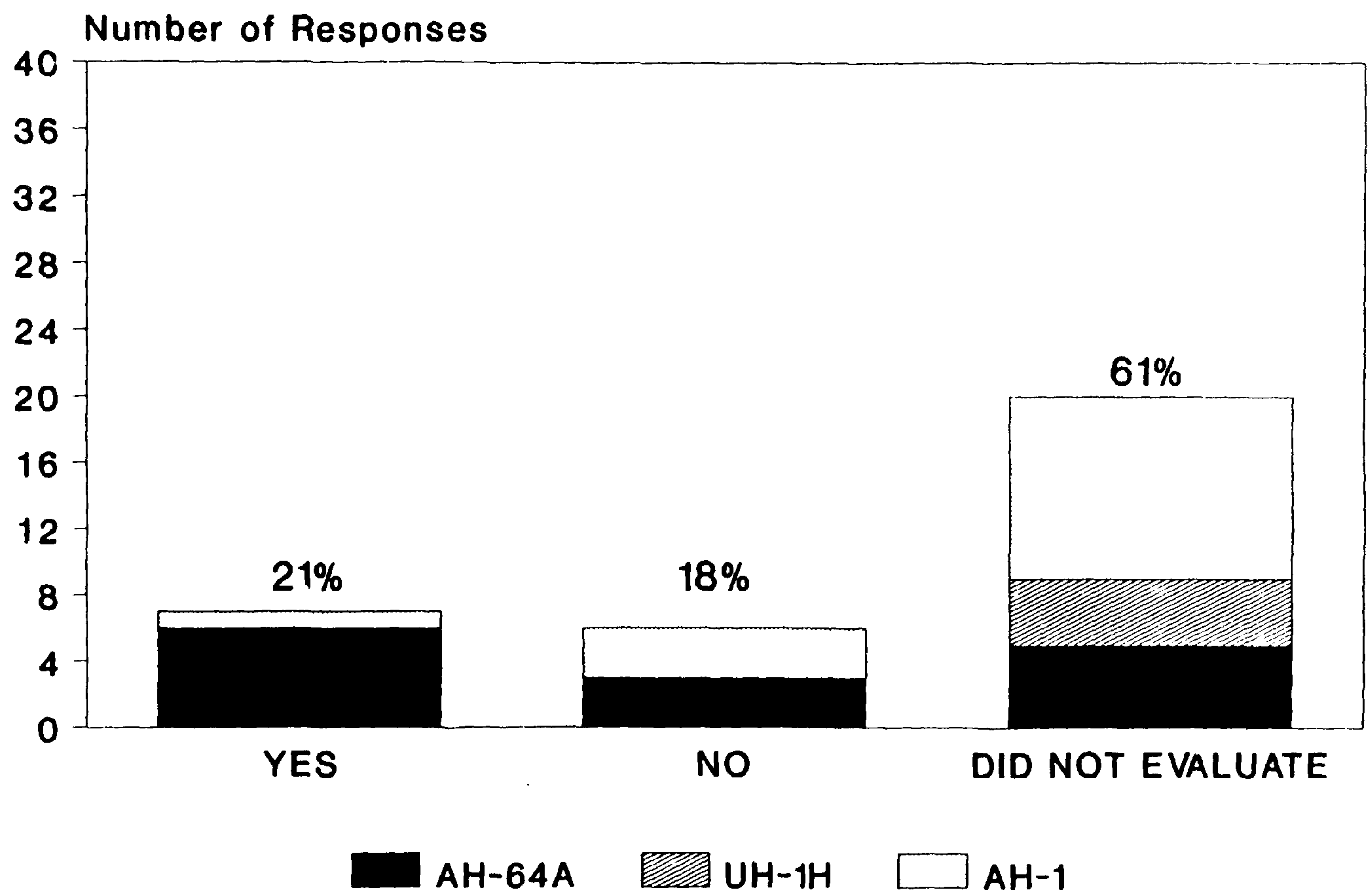
N = 33

Item 3a. Were the CWS display lights easily seen in direct sunlight?



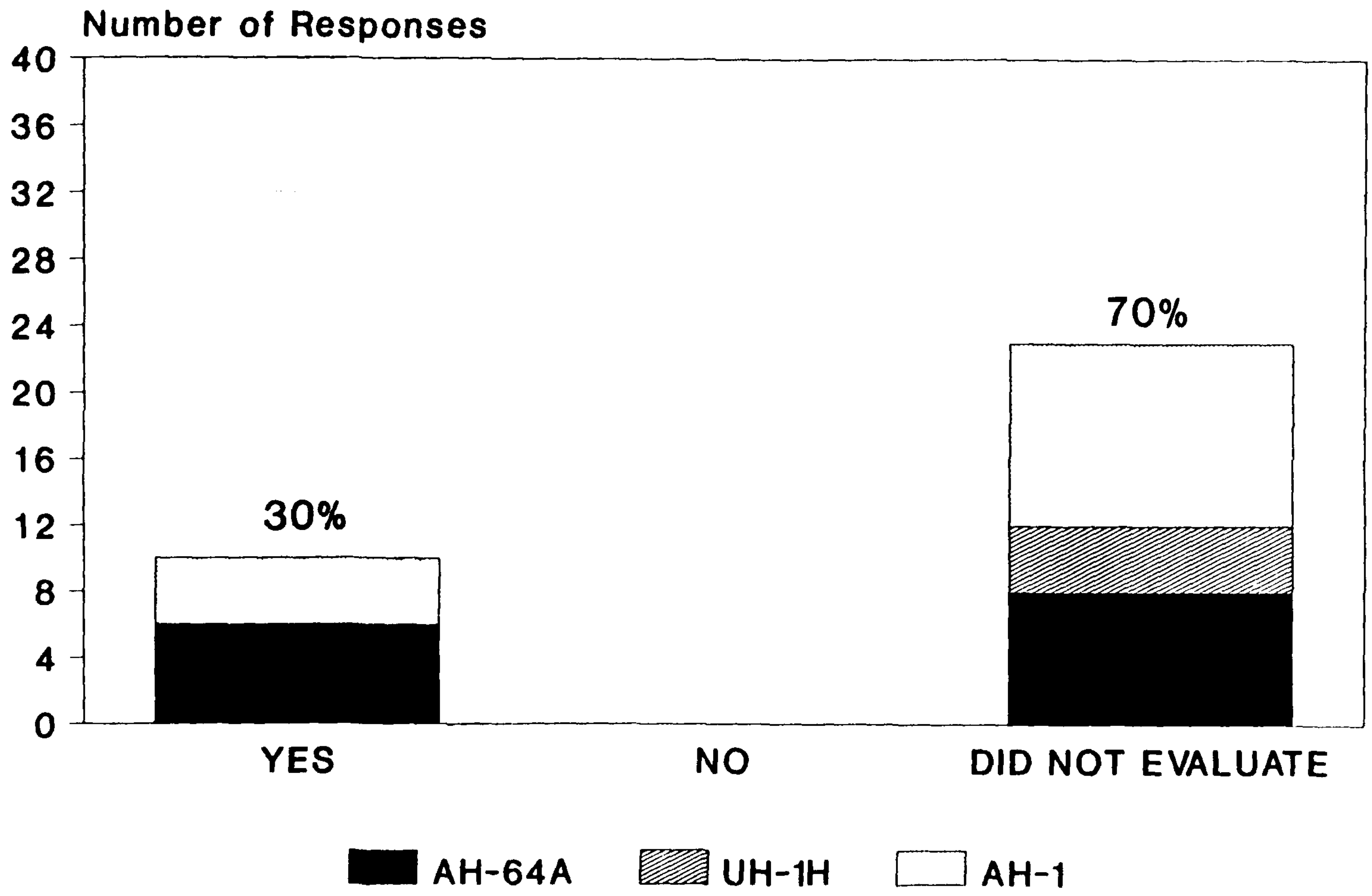
N = 28 / DID NOT EVALUATE = 5

Item 4. Was the CWS display location usable when wearing night vision goggles or the helmet mounted display?



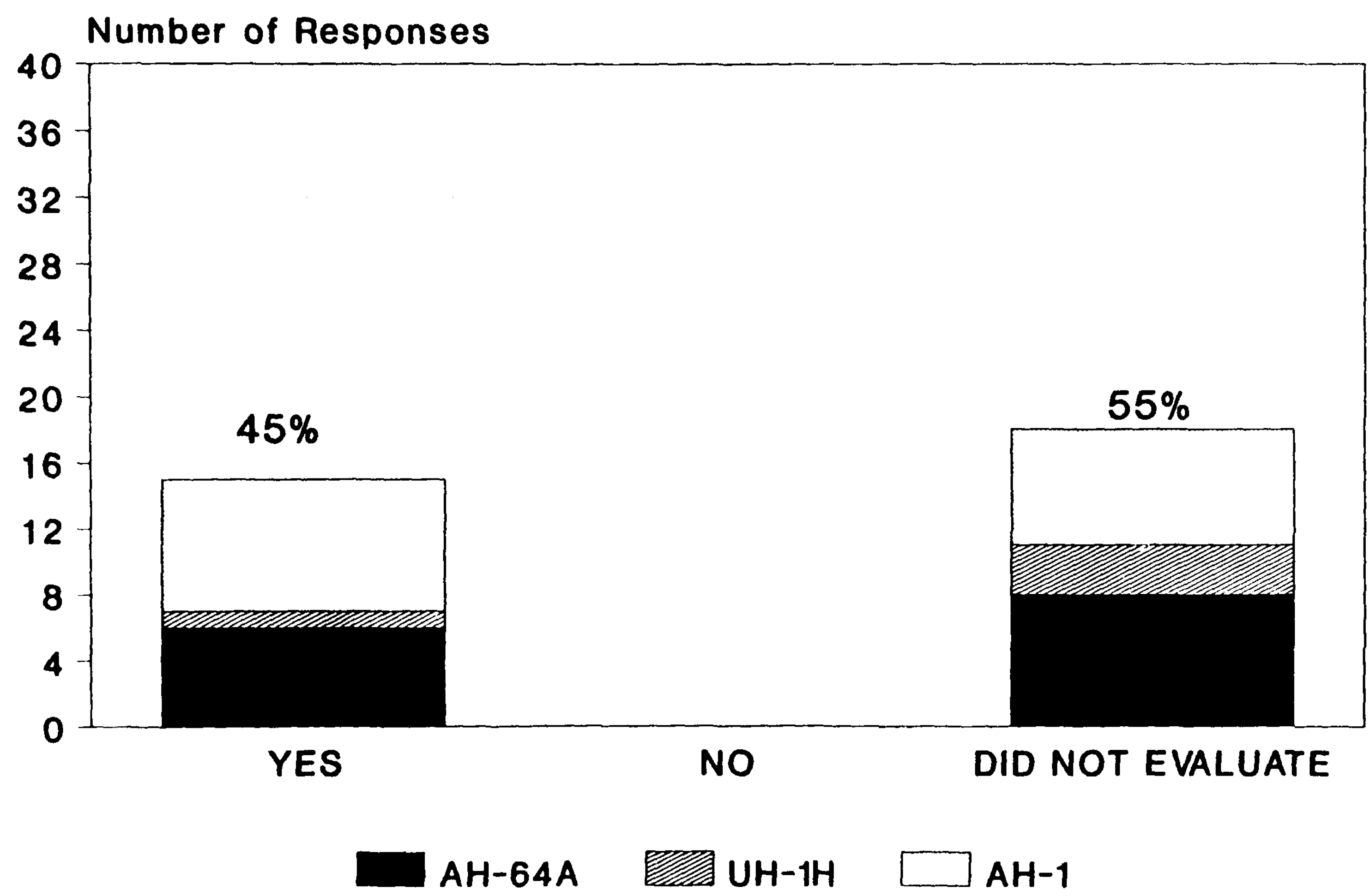
N = 33

Item 5. Were the CWS lights NVG/HMD compatible?



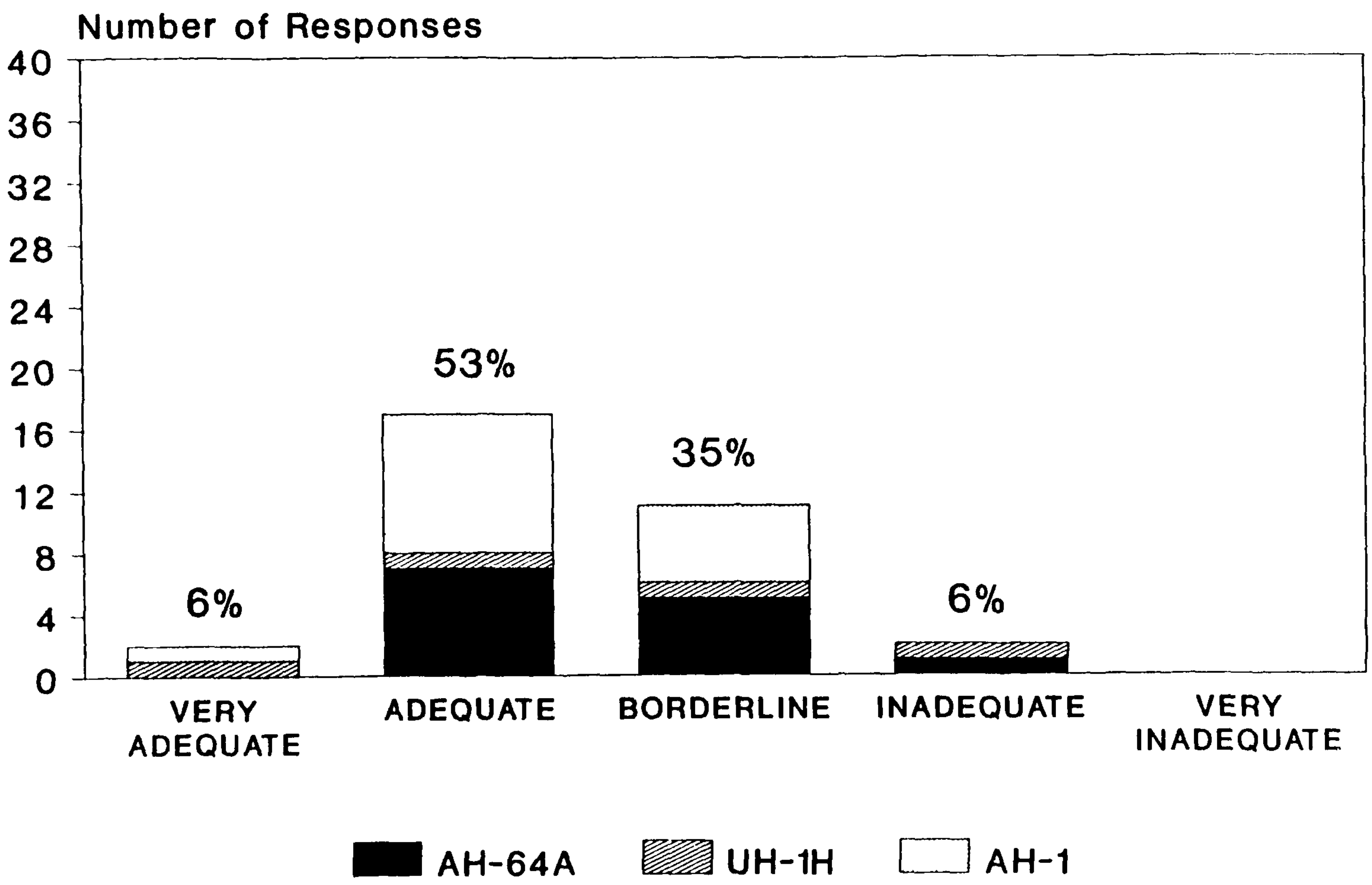
N • 33

Item 6. Were the CWS lights adequate for use during night unaided flight?



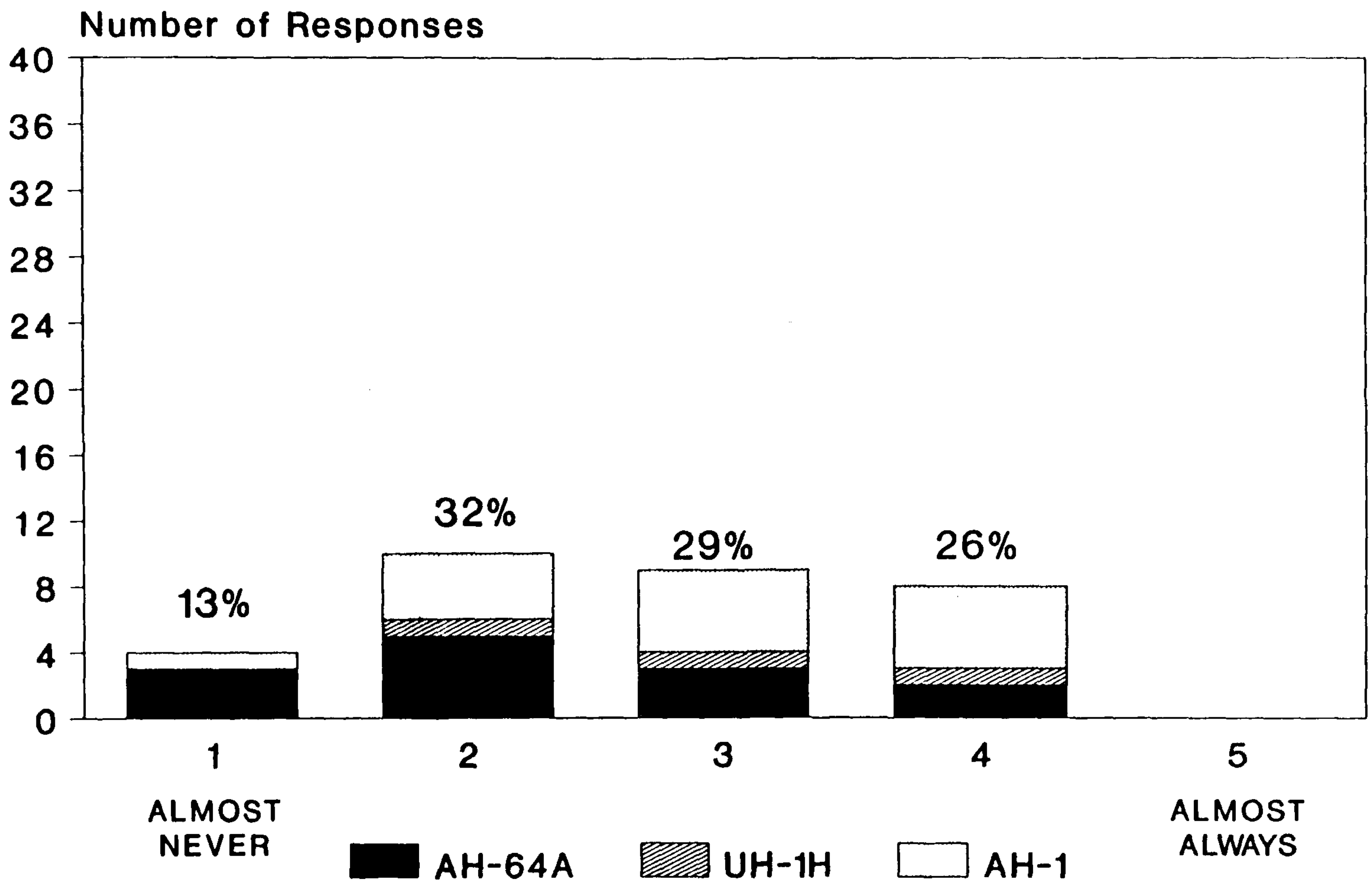
N = 33

Item 7. Did the CWS provide adequate information for you to determine the relative bearing to the wires?



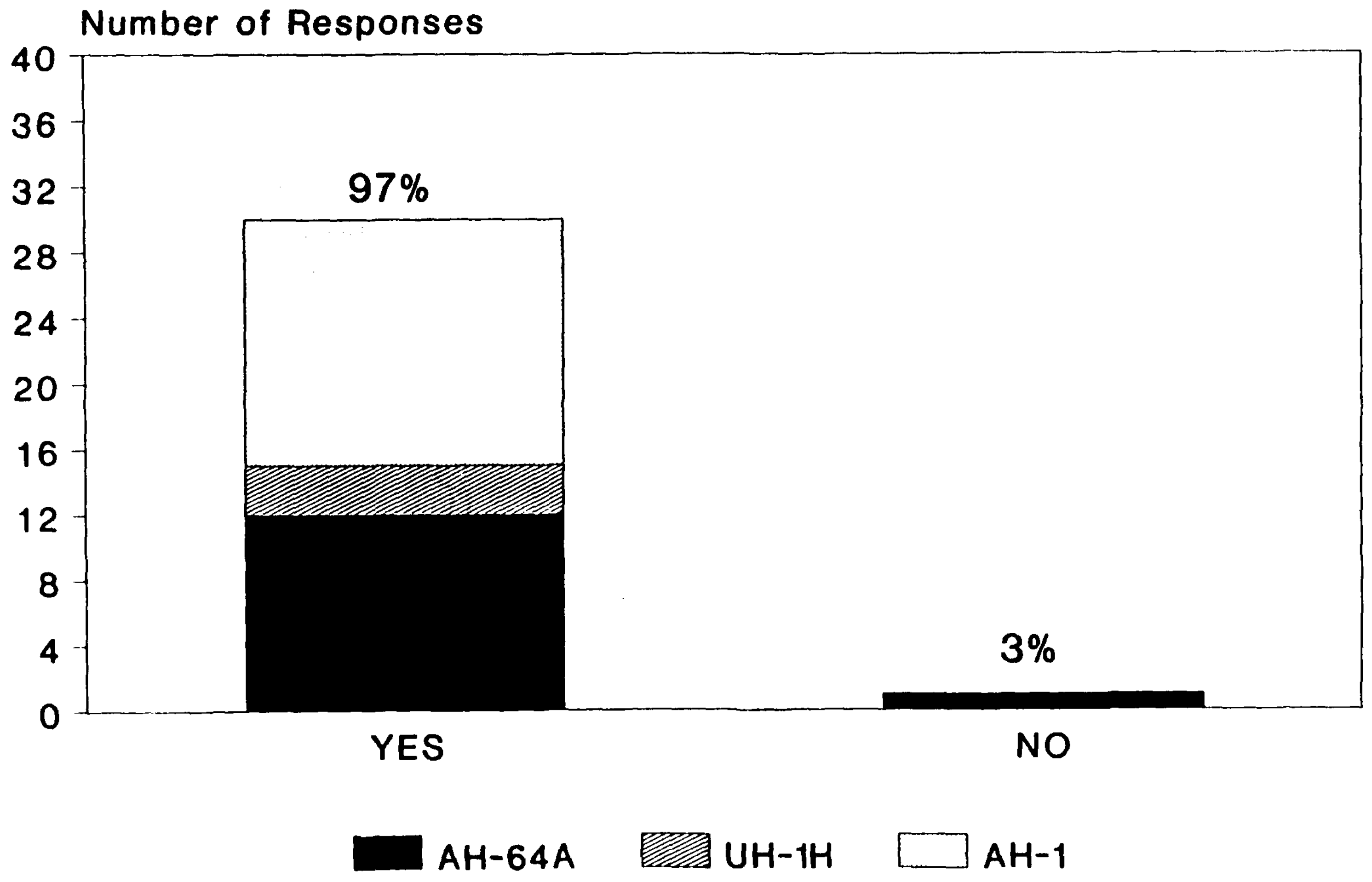
N = 32 / NO RESPONSE = 1

Item 8. In general, did the CWS warn you of the presence of wires in sufficient time to successfully perform an avoidance maneuver?



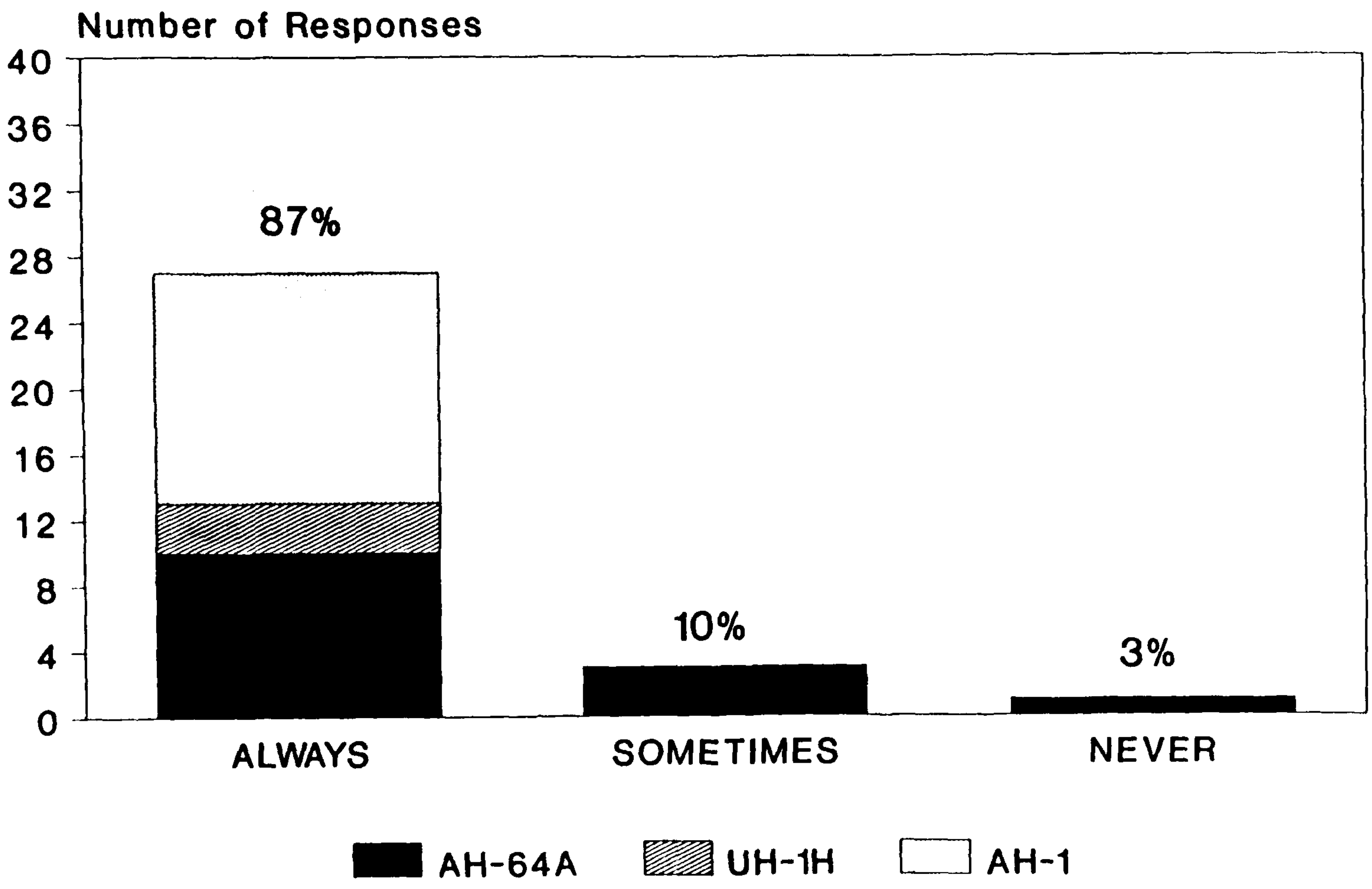
N = 31 / DID NOT EVALUATE = 2

Item 9. Was there ever a case where CWS did not warn you in time to successfully perform an avoidance maneuver?



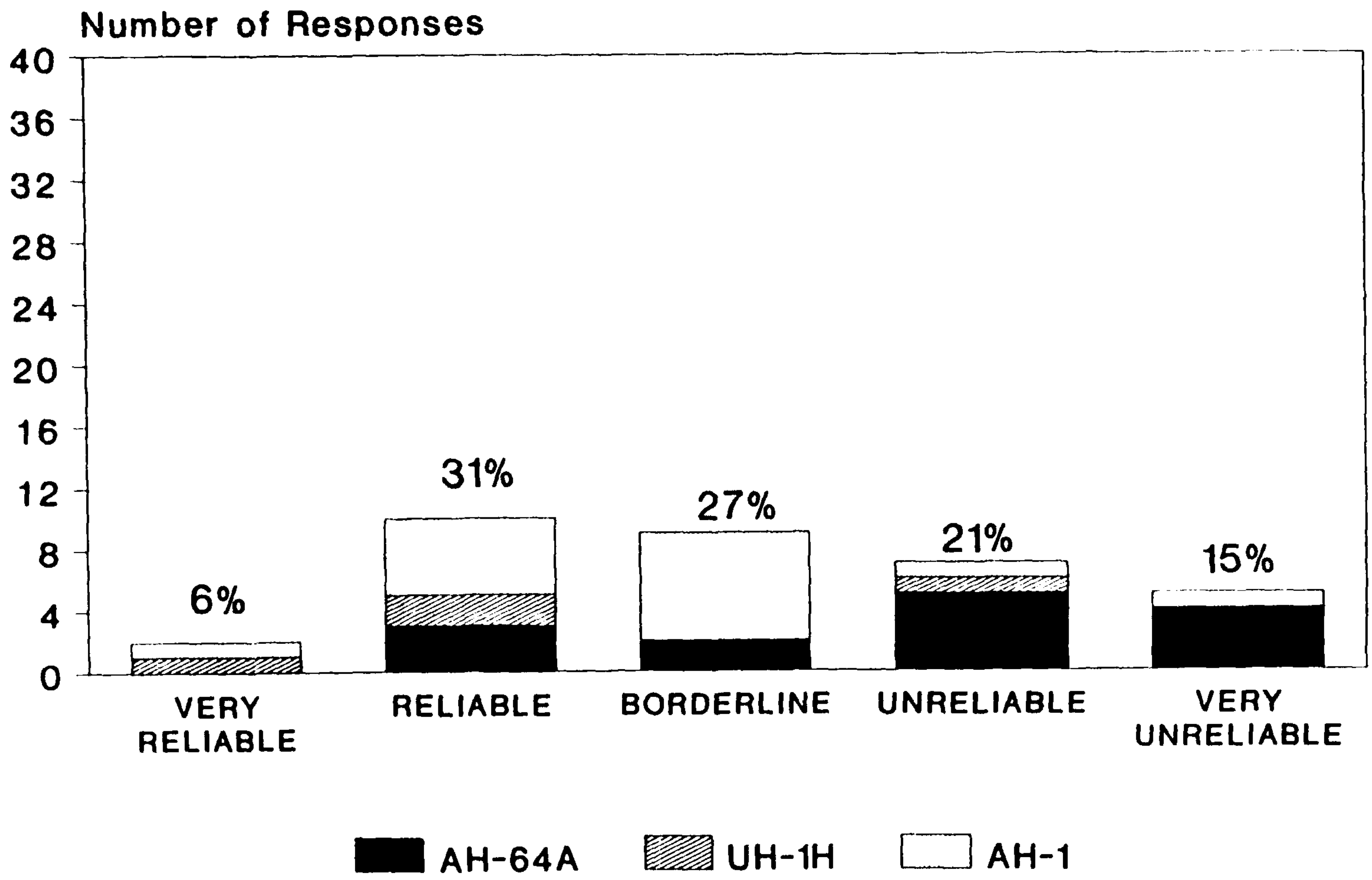
N = 31 / NO RESPONSE = 2

Item 10. When CWS indicated that wires were in the vicinity, did you visually verify the presence/location of the wires before starting an evasive maneuver?



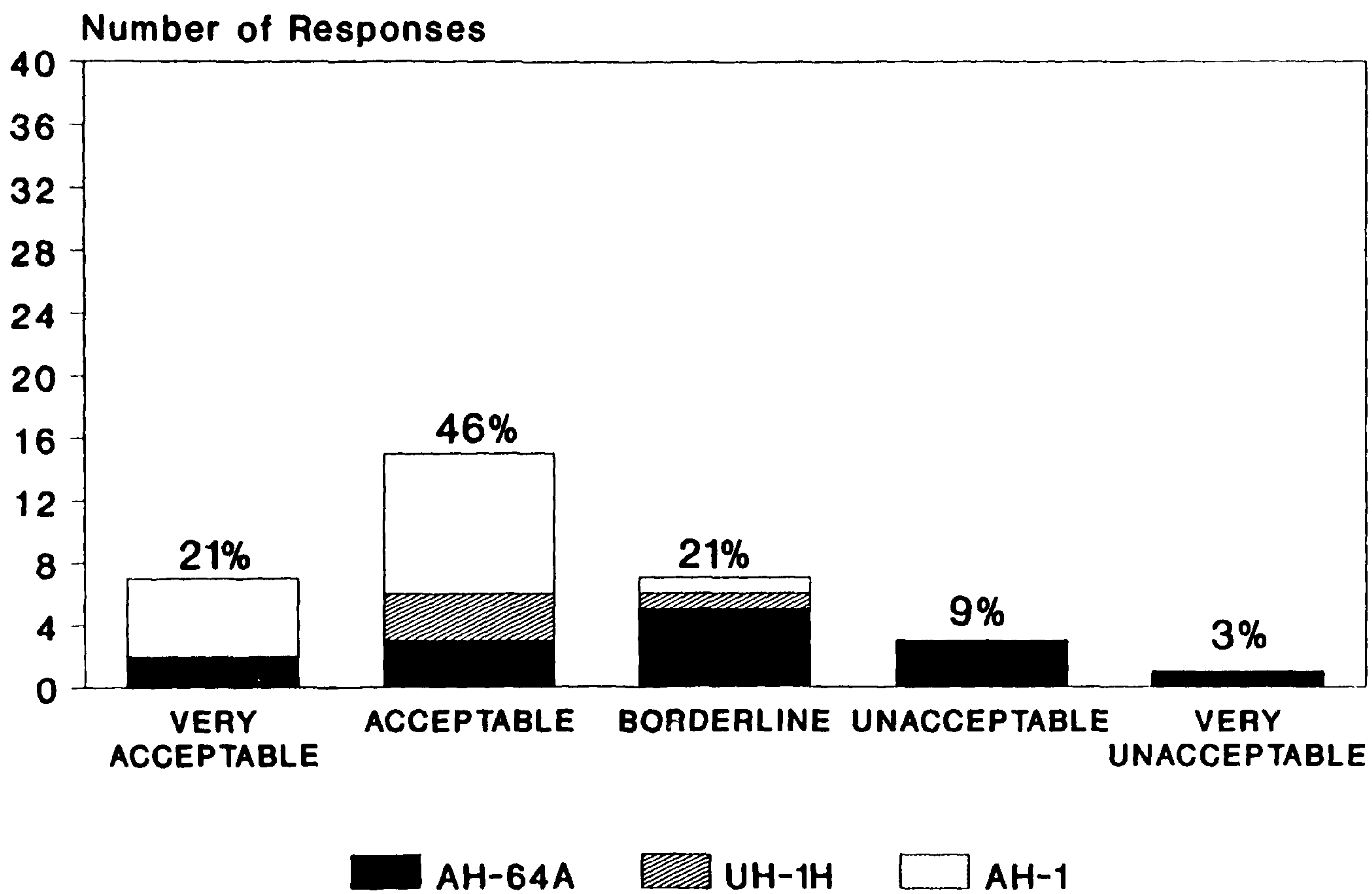
N = 31 / NO RESPONSE = 2

Item 11. Was the CWS a reliable indicator that wires were in the vicinity (that is, when a wire is present, did the CWS provide an indication)?



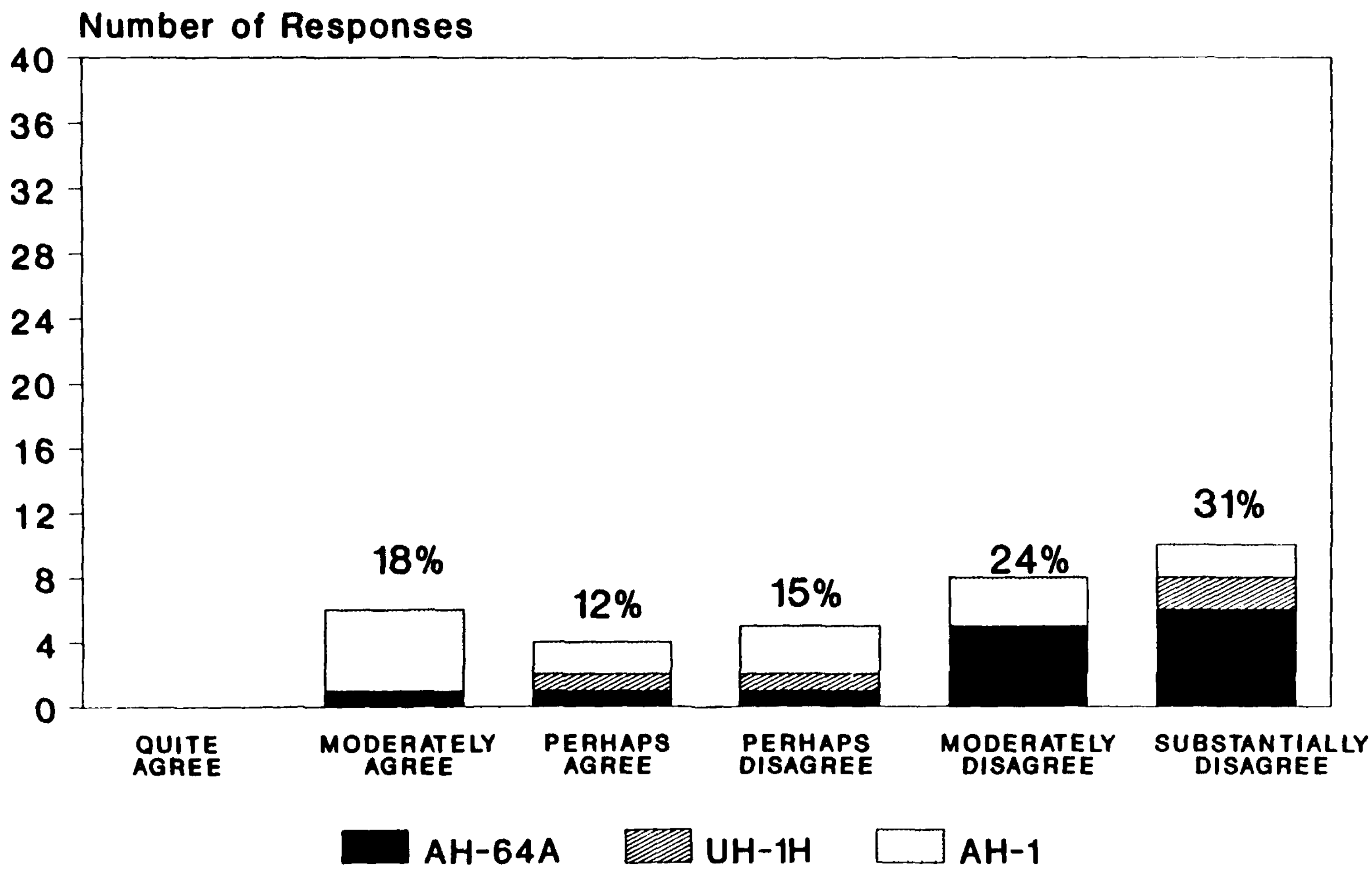
N = 33

Item 12. Evaluate the false alarm rate of the CWS (a false alarm is when the CWS indicates wires are present, but no wires are in the vicinity).



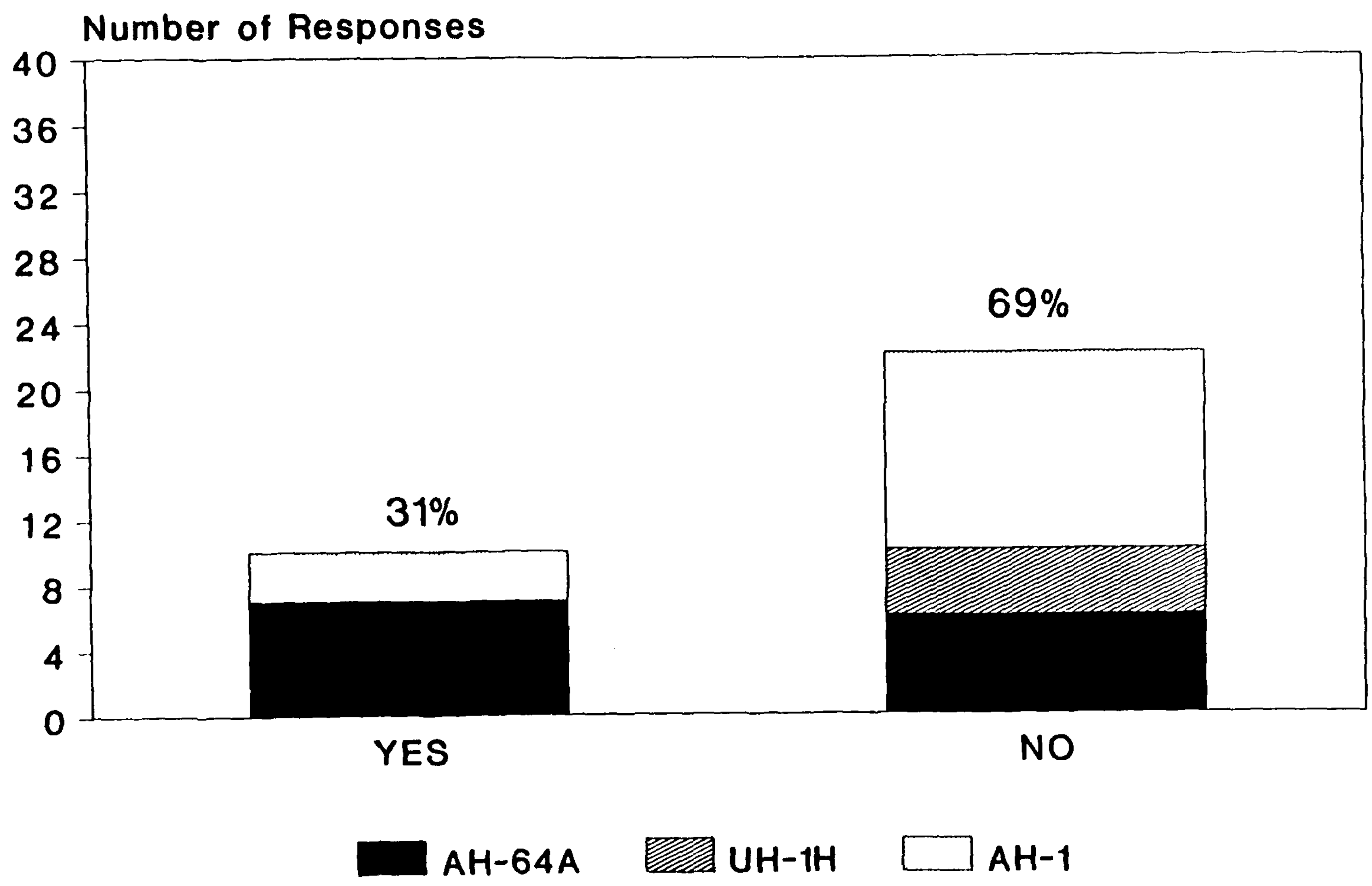
N = 33

Item 13. The CWS will help to provide a substantial reduction in helicopter wire strike accidents.



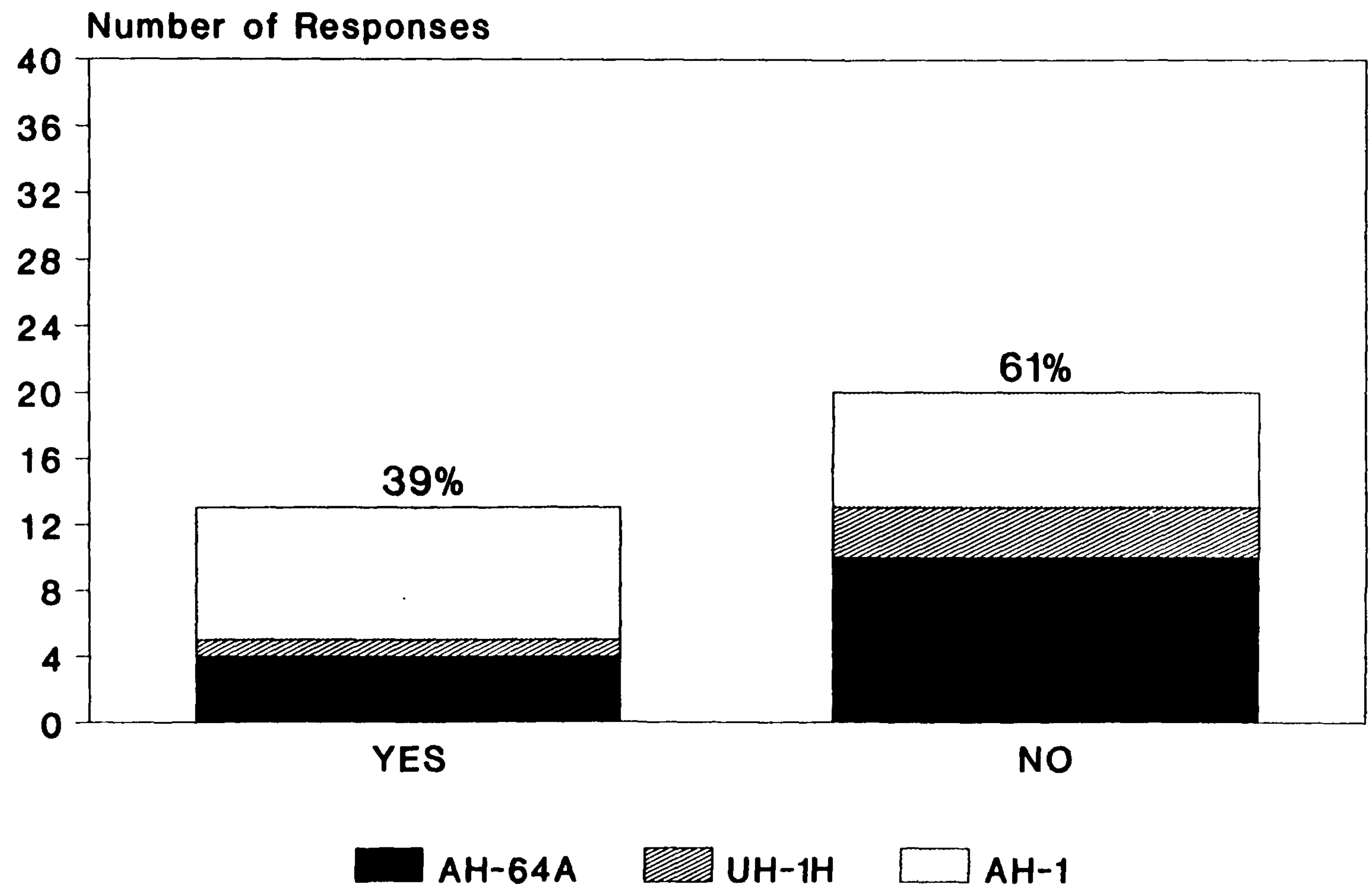
N = 33

Item 14. Is the CWS display lacking any information that is needed to make the system more effective?



N = 32 / NO RESPONSE = 1

Item 15. Overall, do you believe that the CWS will help aviators avoid wire strikes?

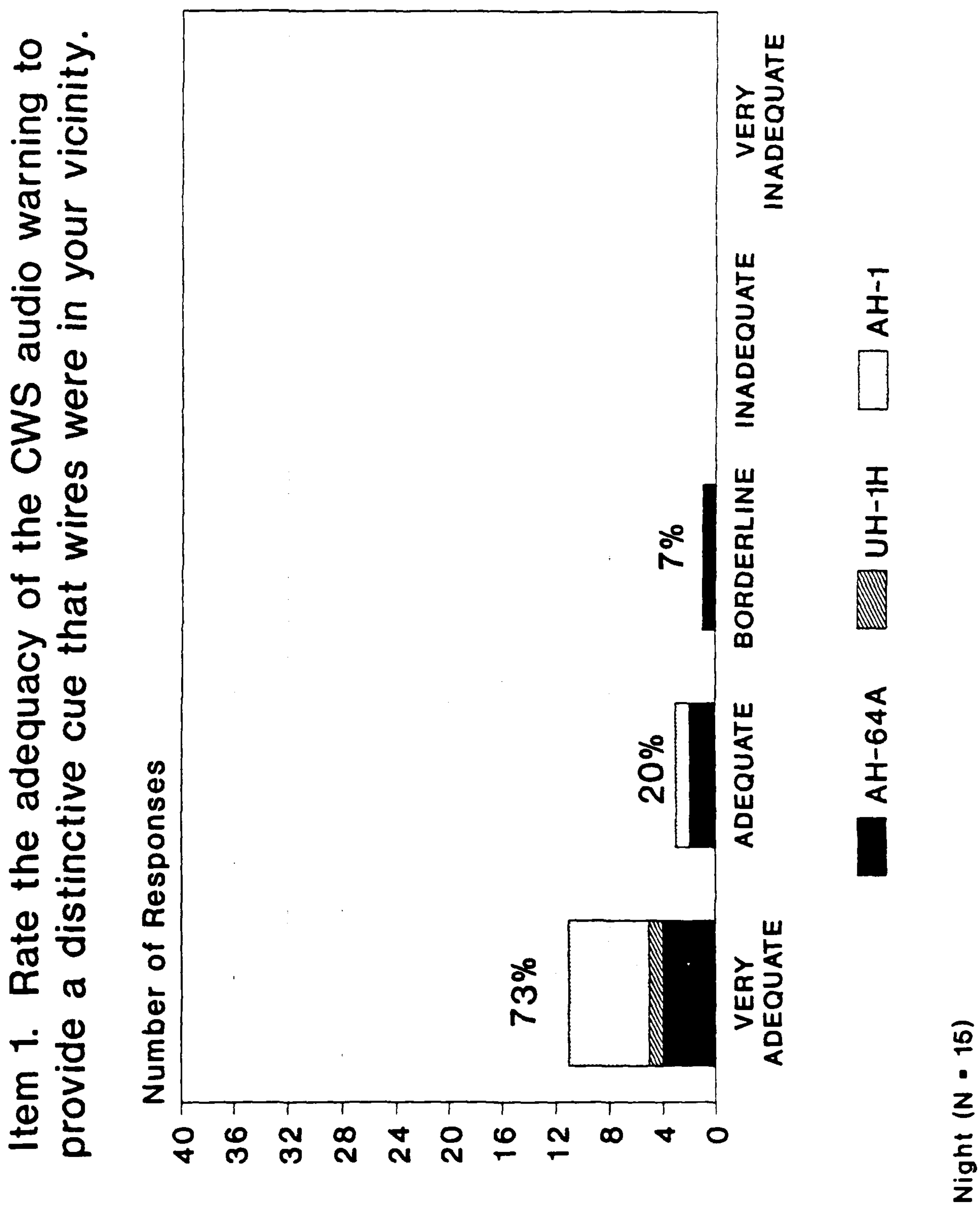


N = 33

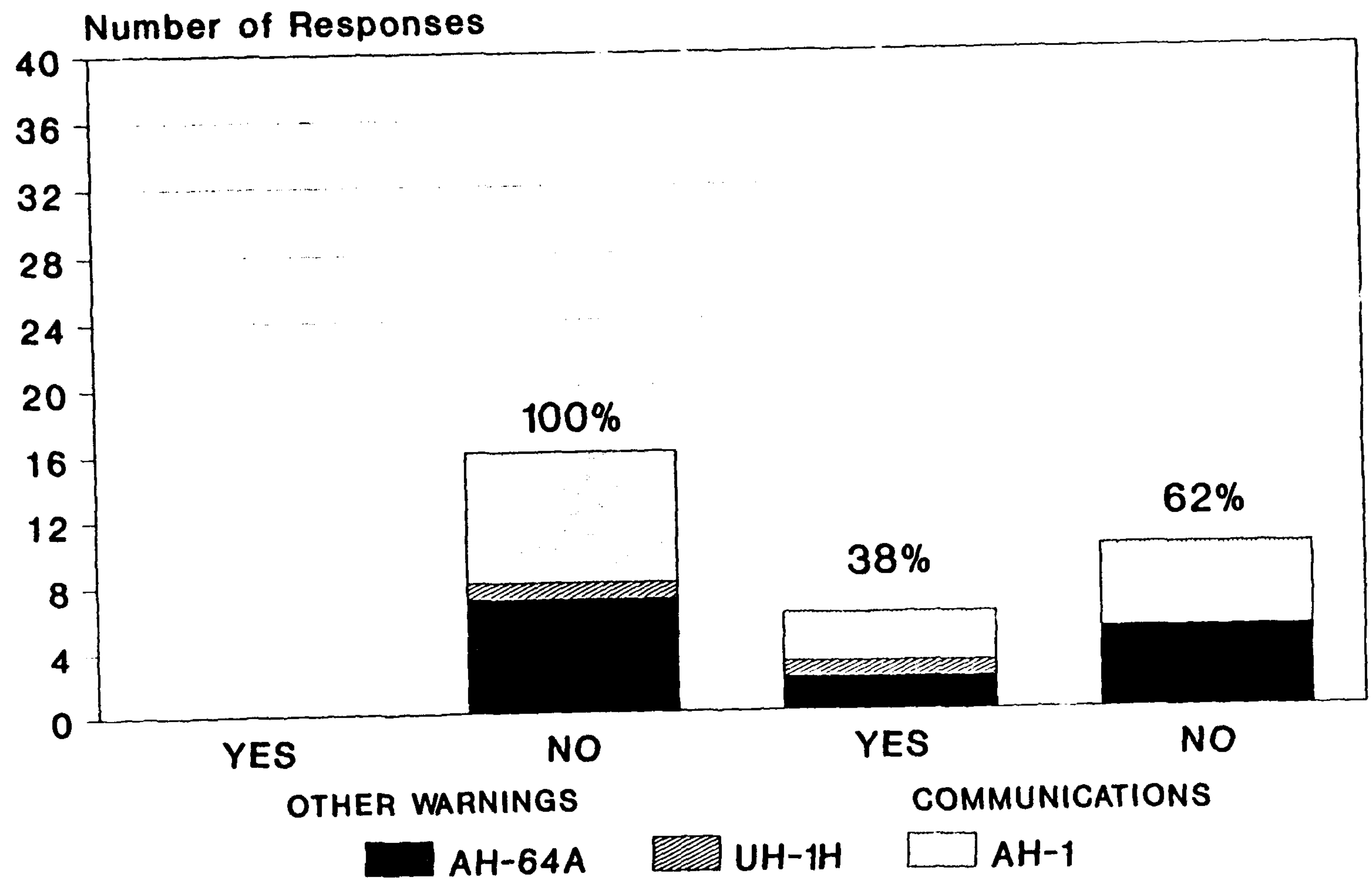
APPENDIX C

RESULTS OF CWS QUESTIONNAIRE FOR PILOTS USING CWS AT NIGHT

(Aided and Unaided) (16 Participants)

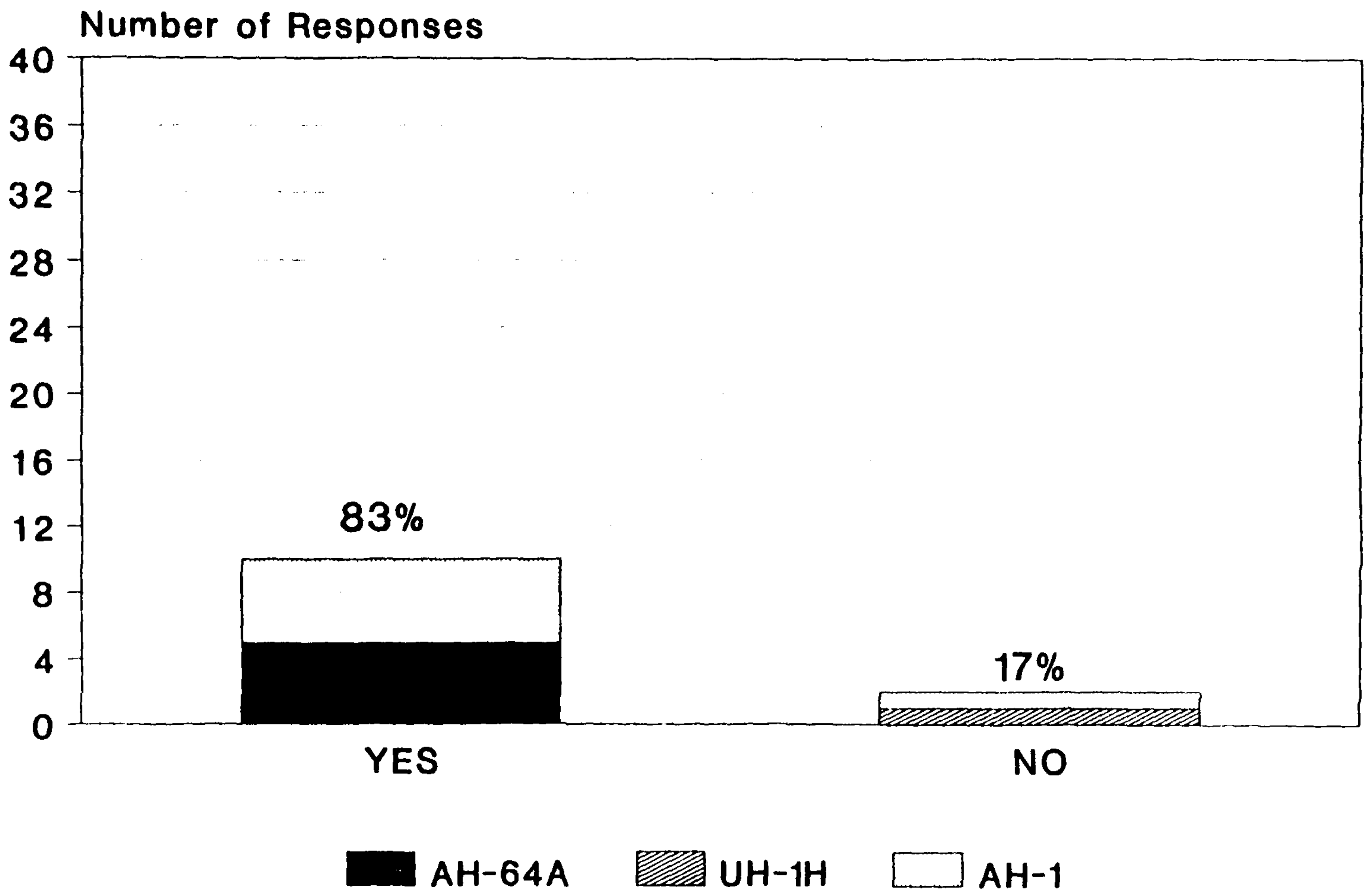


Item 2. Did the CWS audio warnings interfere with other audio warnings or with communications?



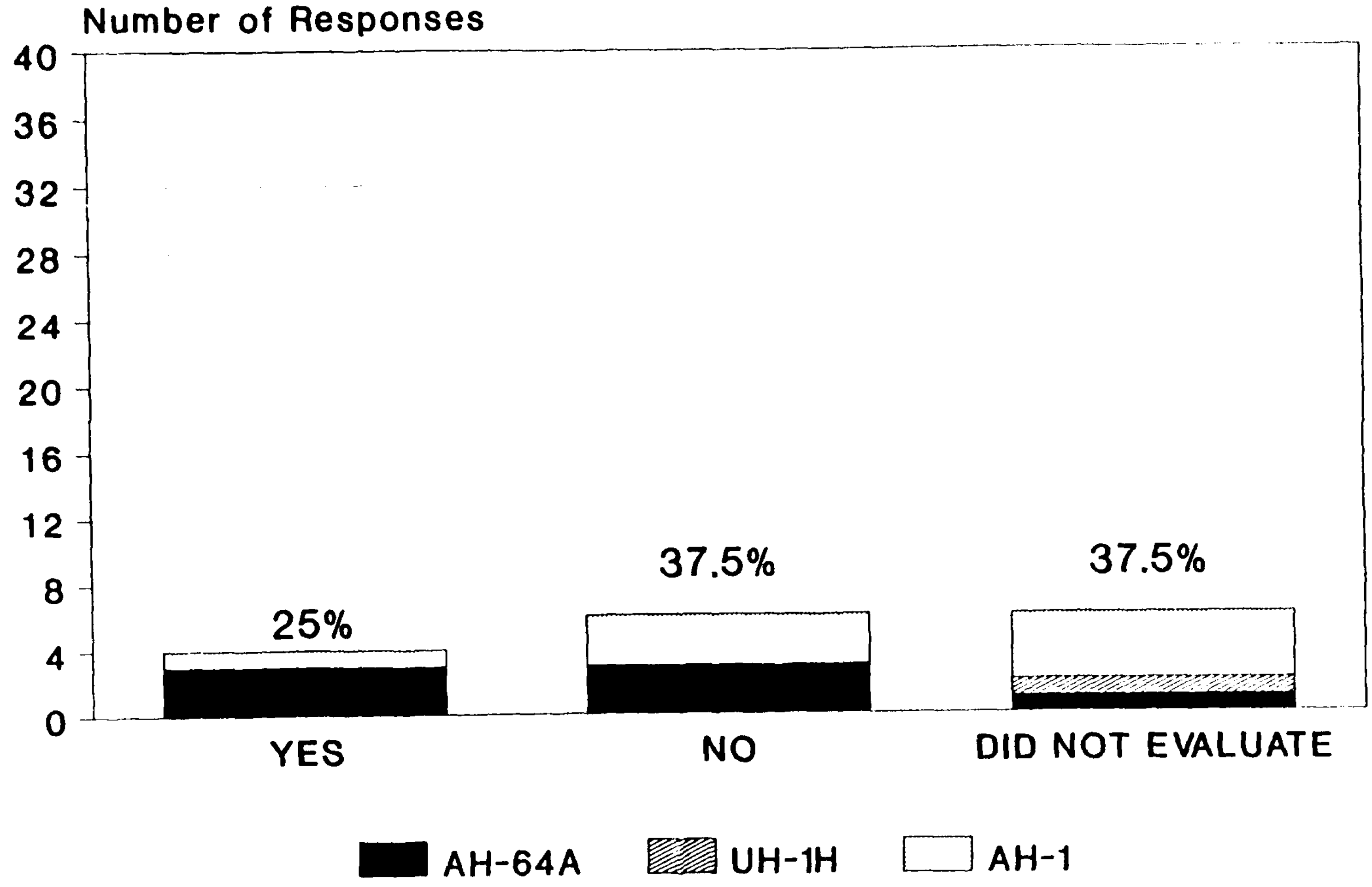
Night (N = 16)

Item 3a. Were the CWS display lights easily seen in direct sunlight?



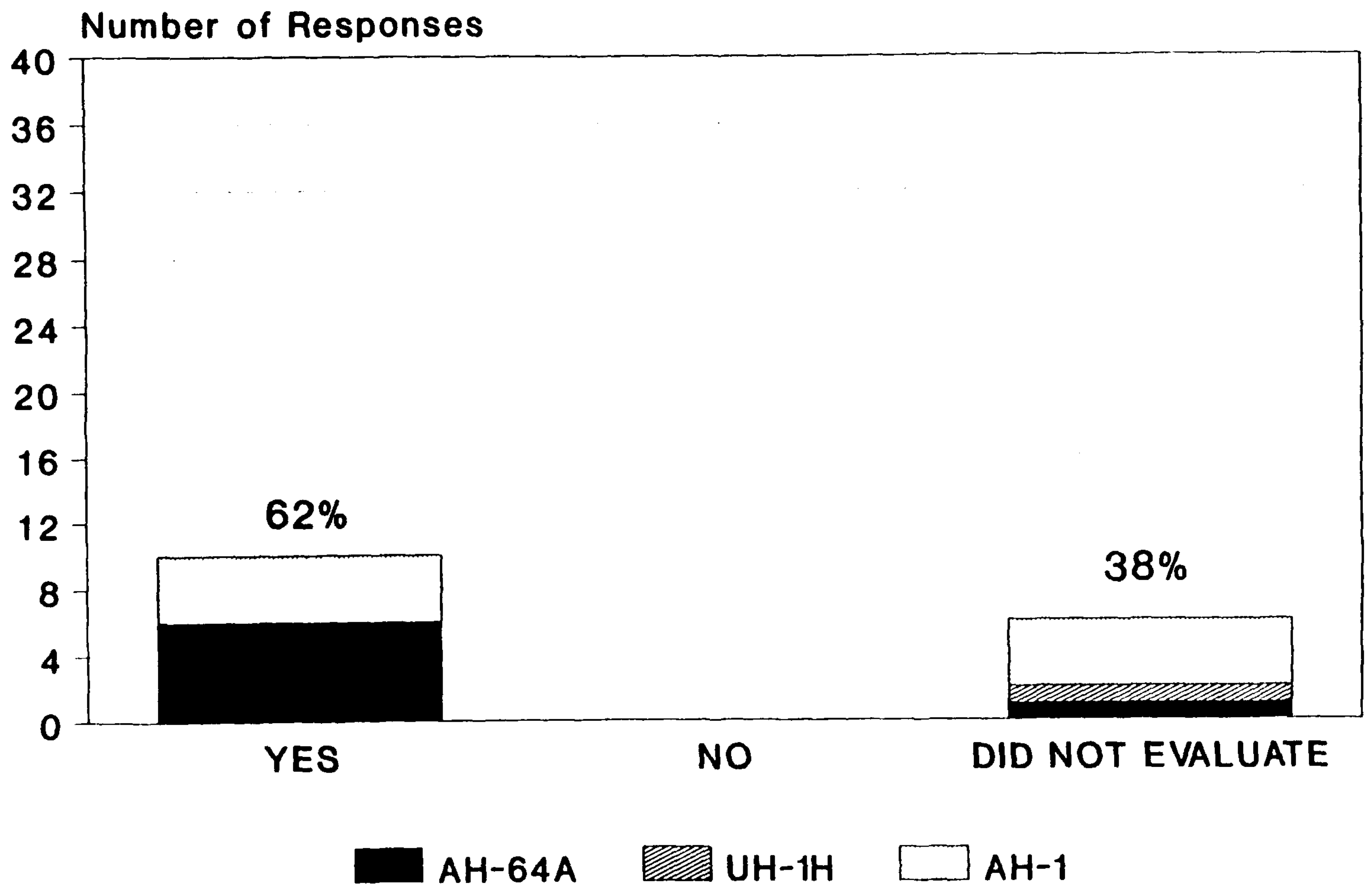
Night (N = 12)

Item 4. Was the CWS display location usable when wearing night vision goggles or the helmet mounted display?



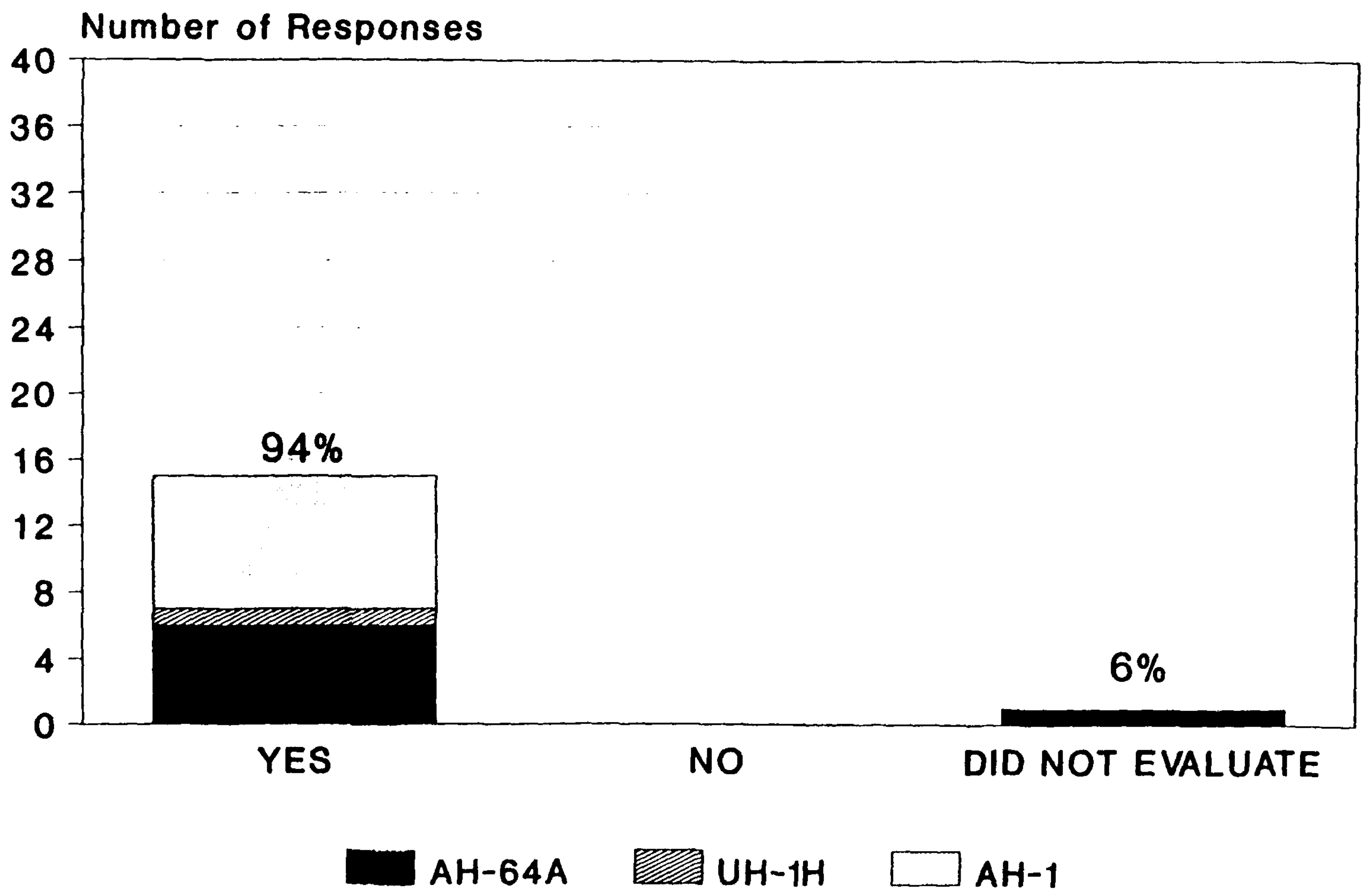
Night (N = 16)

Item 5. Were the CWS lights NVG/HMD compatible?



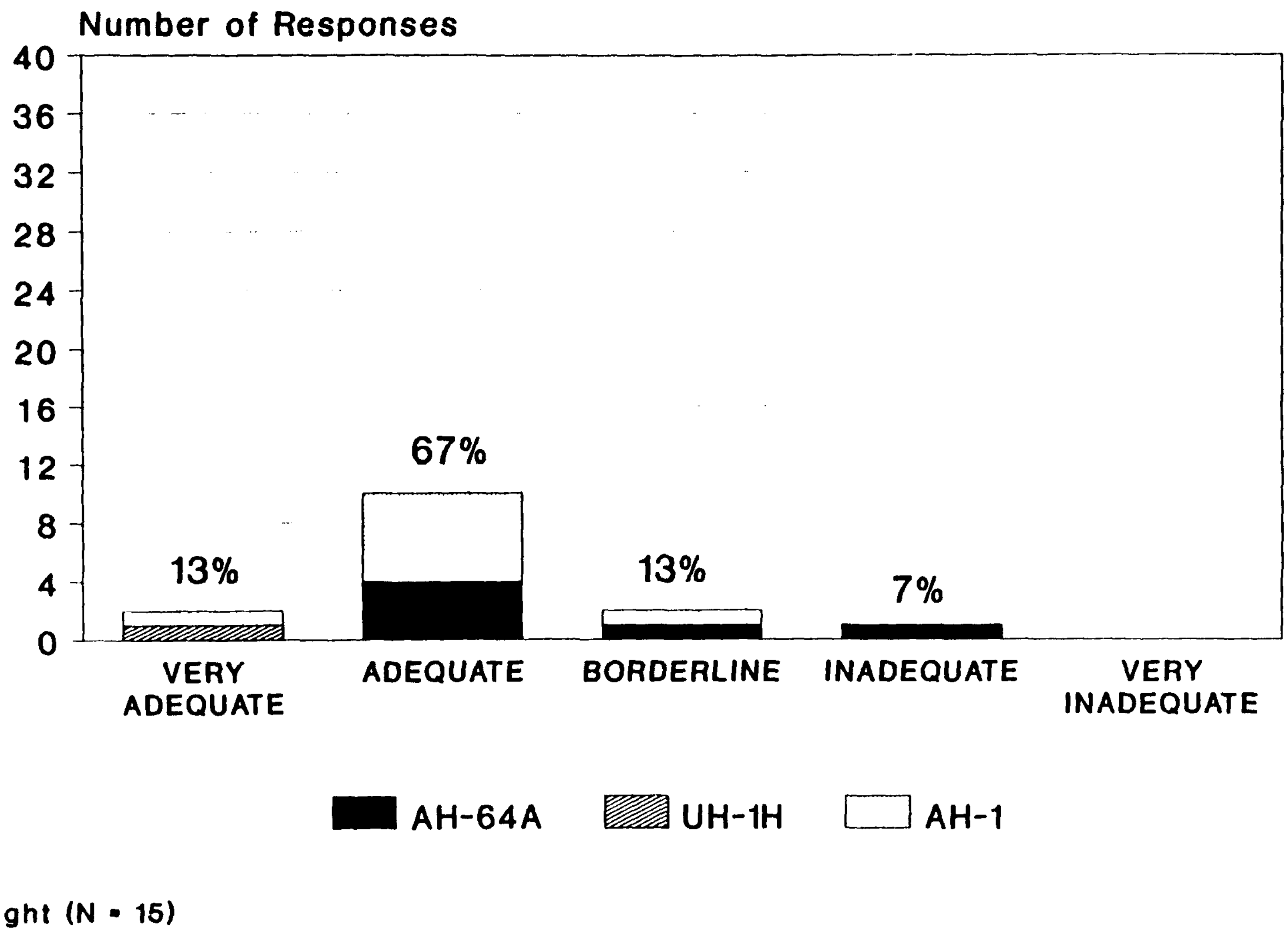
Night (N = 16)

Item 6. Were the CWS lights adequate for use during night unaided flight?

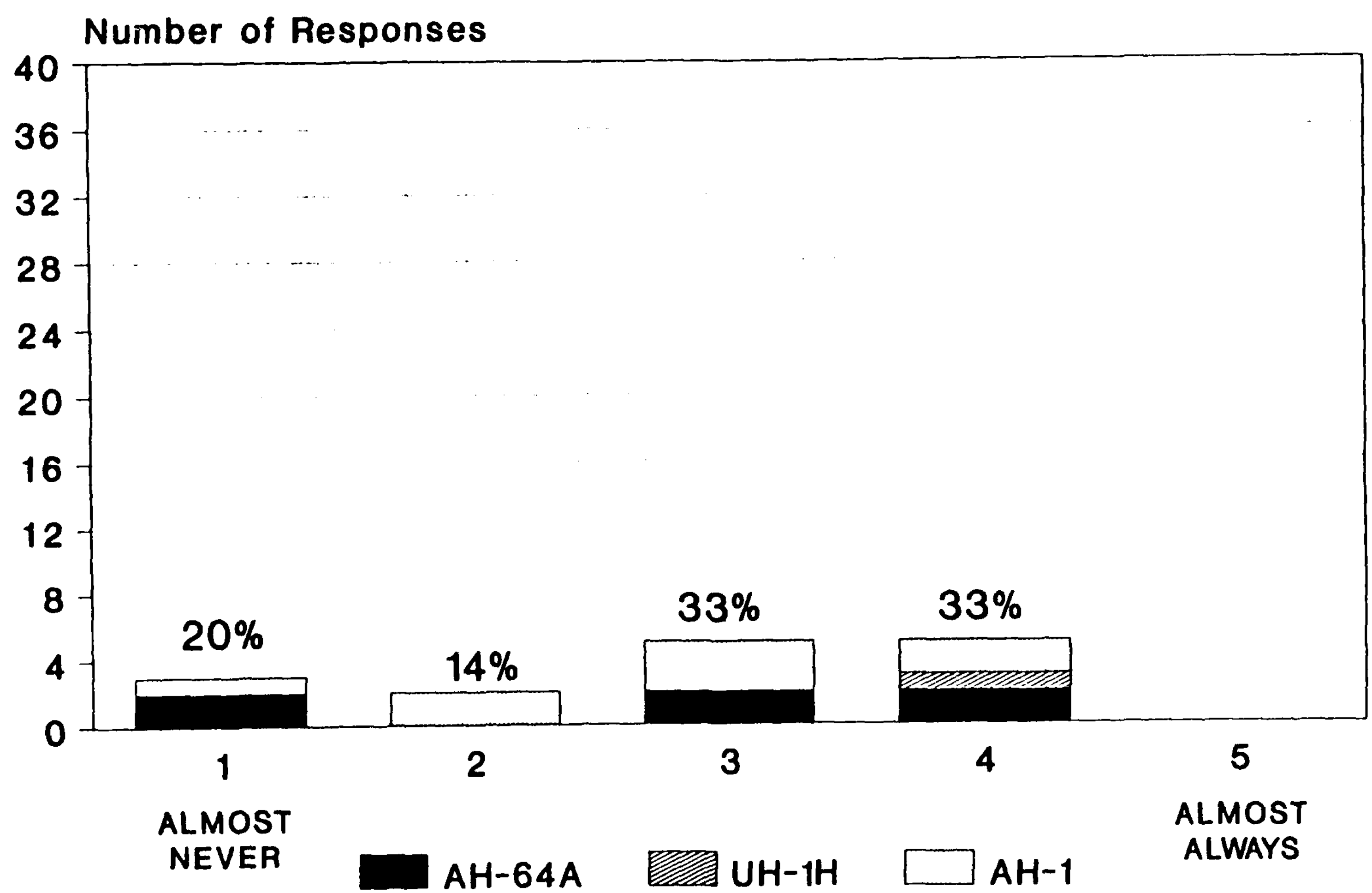


Night (N = 16)

Item 7. Did the CWS provide adequate information for you to determine the relative bearing to the wires?

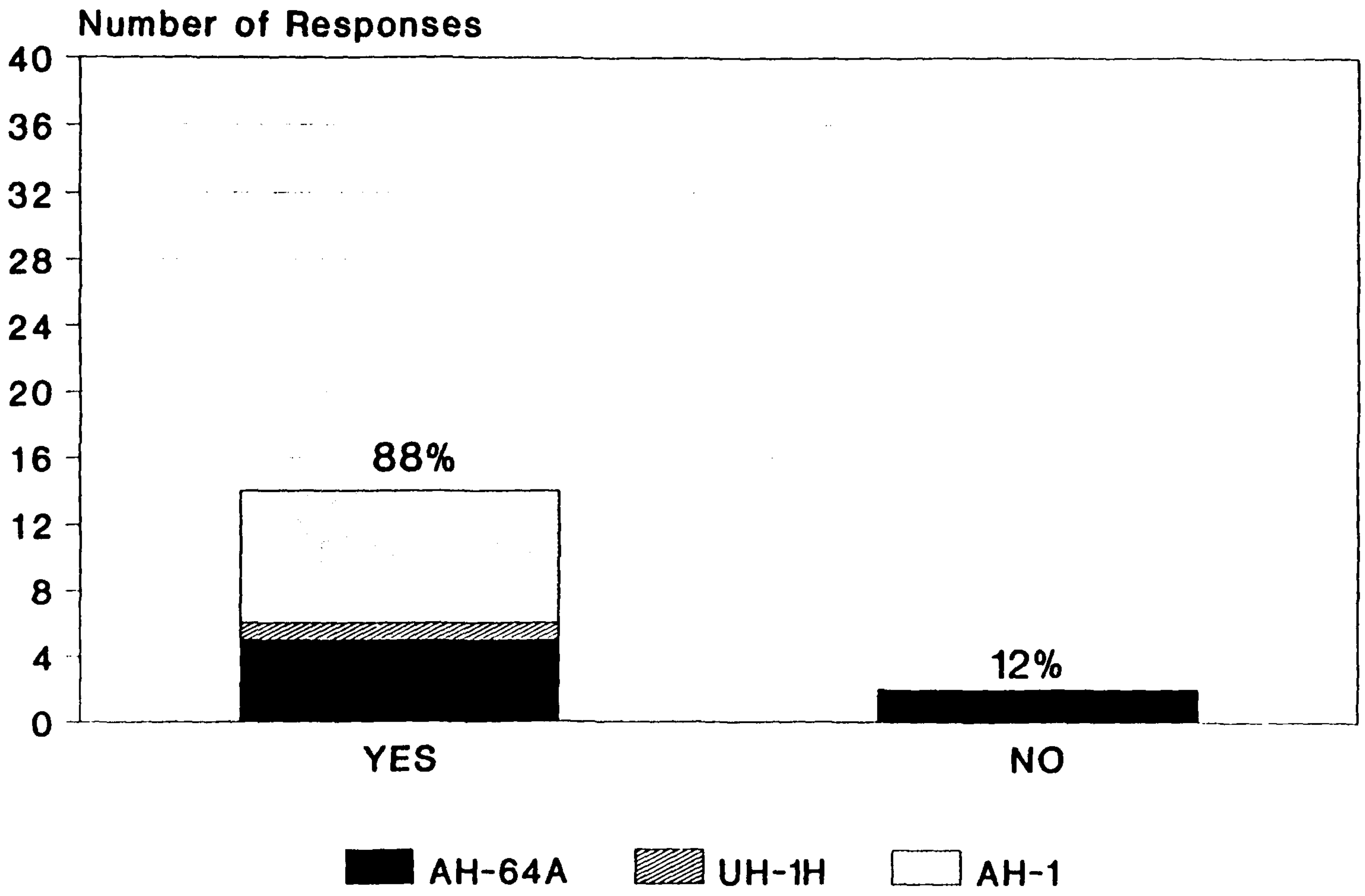


Item 8. In general, did the CWS warn you of the presence of wires in sufficient time to successfully perform an avoidance maneuver?



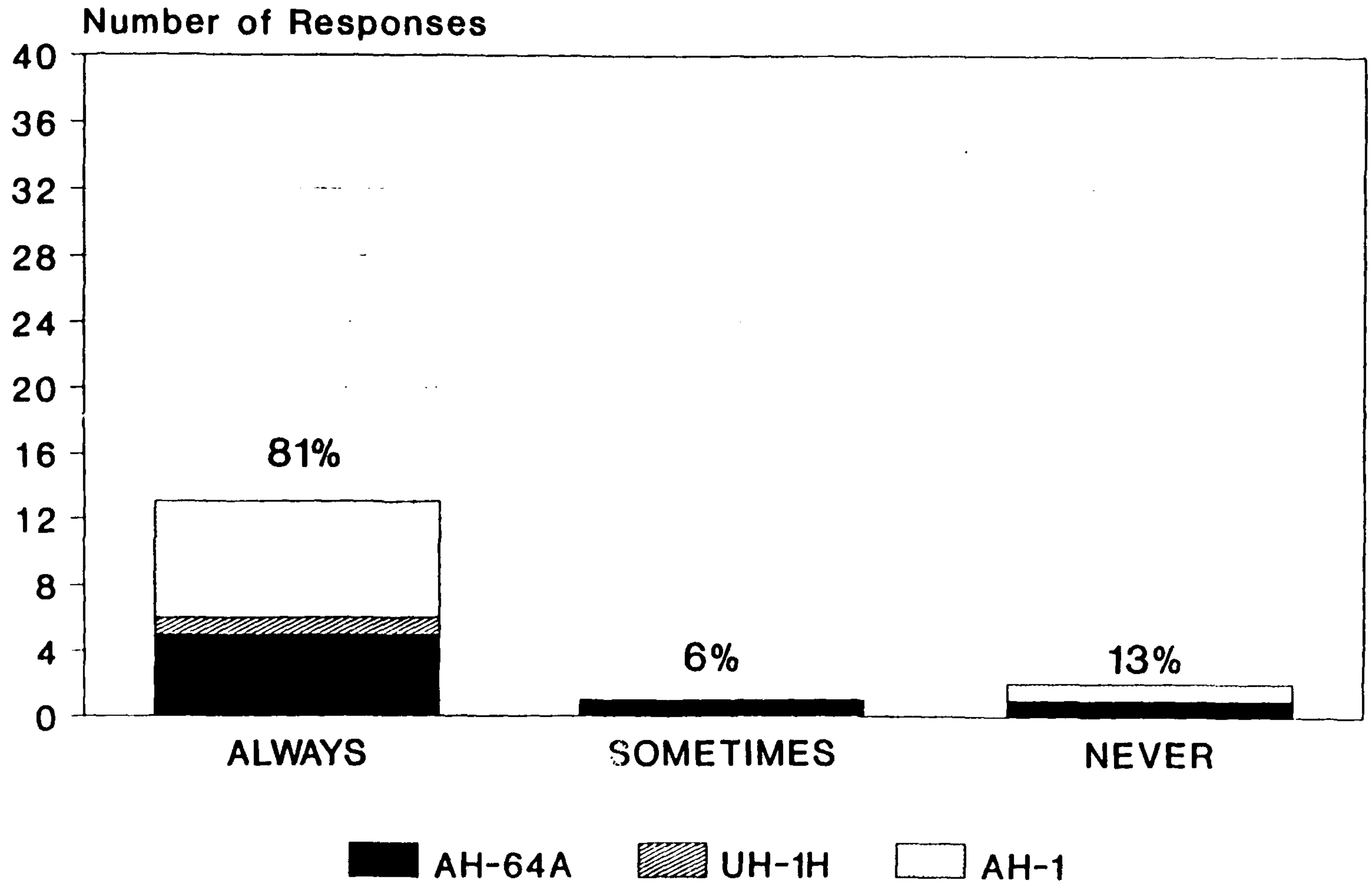
Night (N = 15)

Item 9. Was there ever a case where CWS did not warn you in time to successfully perform an avoidance maneuver?



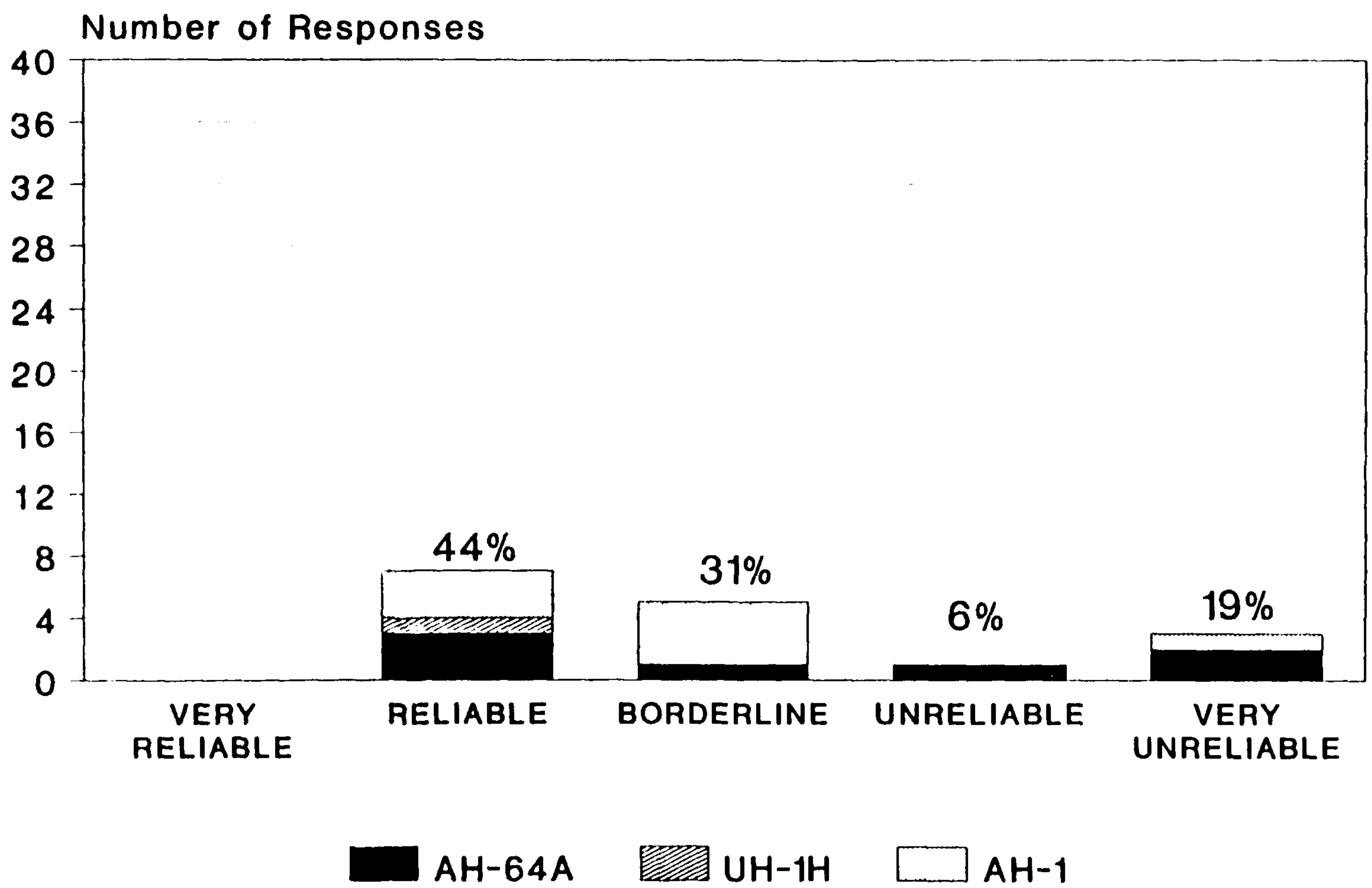
Night (N = 16)

Item 10. When CWS indicated that wires were in the vicinity, did you visually verify the presence/location of the wires before starting an evasive maneuver?



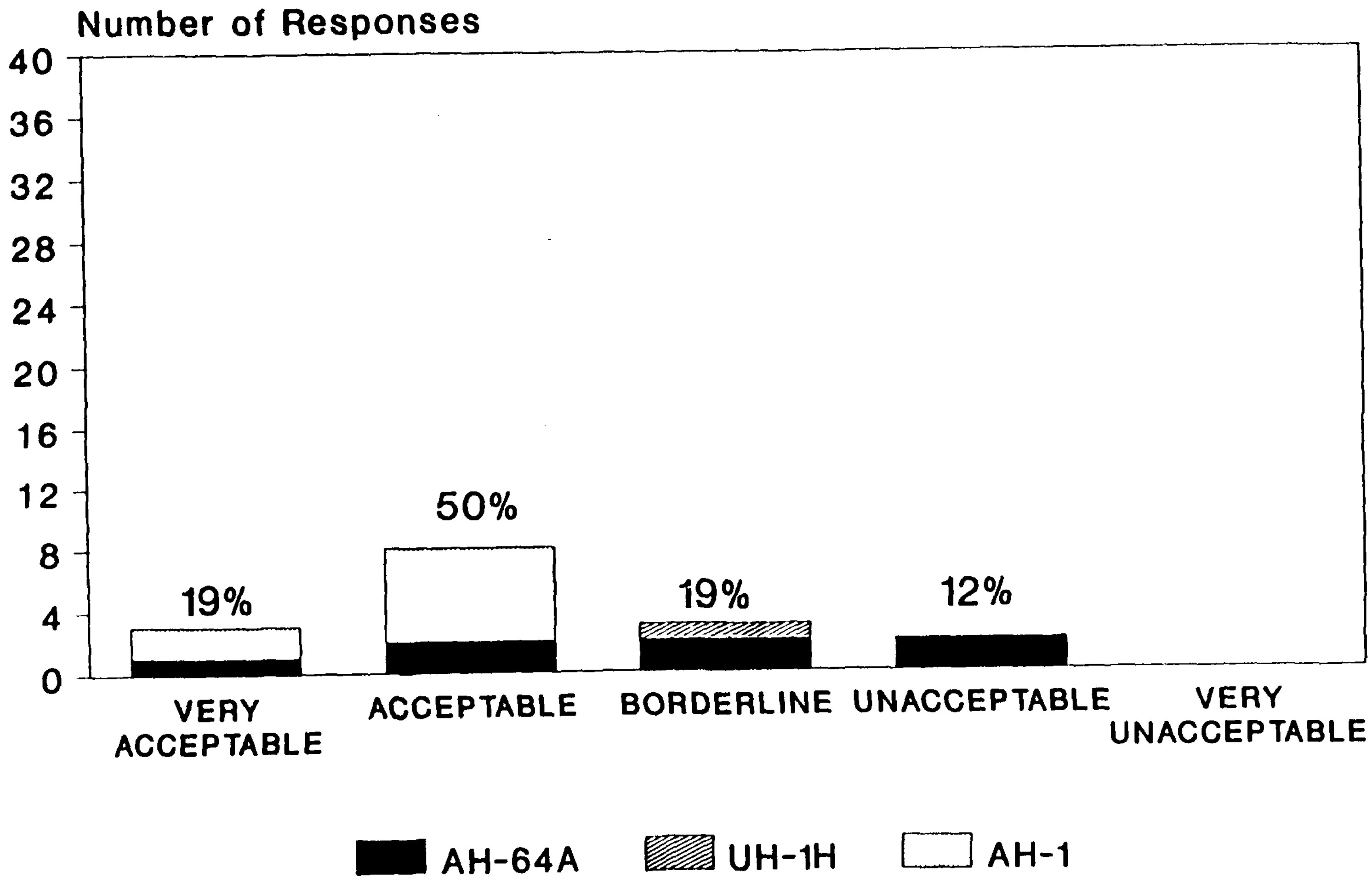
Night (N = 16)

Item 11. Was the CWS a reliable indicator that wires were in the vicinity (that is, when a wire is present, did the CWS provide an indication)?



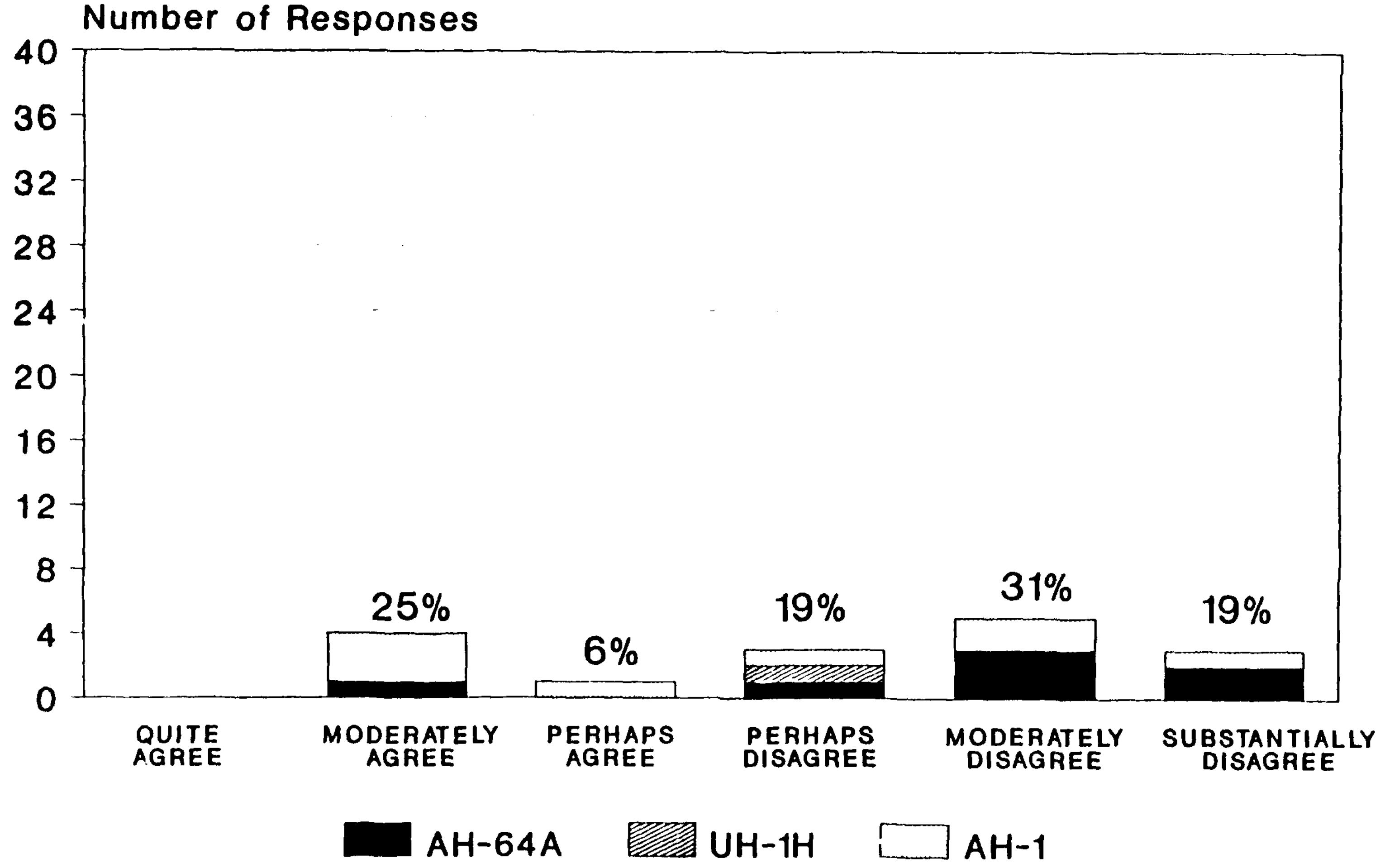
Night (N = 16)

Item 12. Evaluate the false alarm rate of the CWS (a false alarm is when the CWS indicates wires are present, but no wires are in the vicinity).



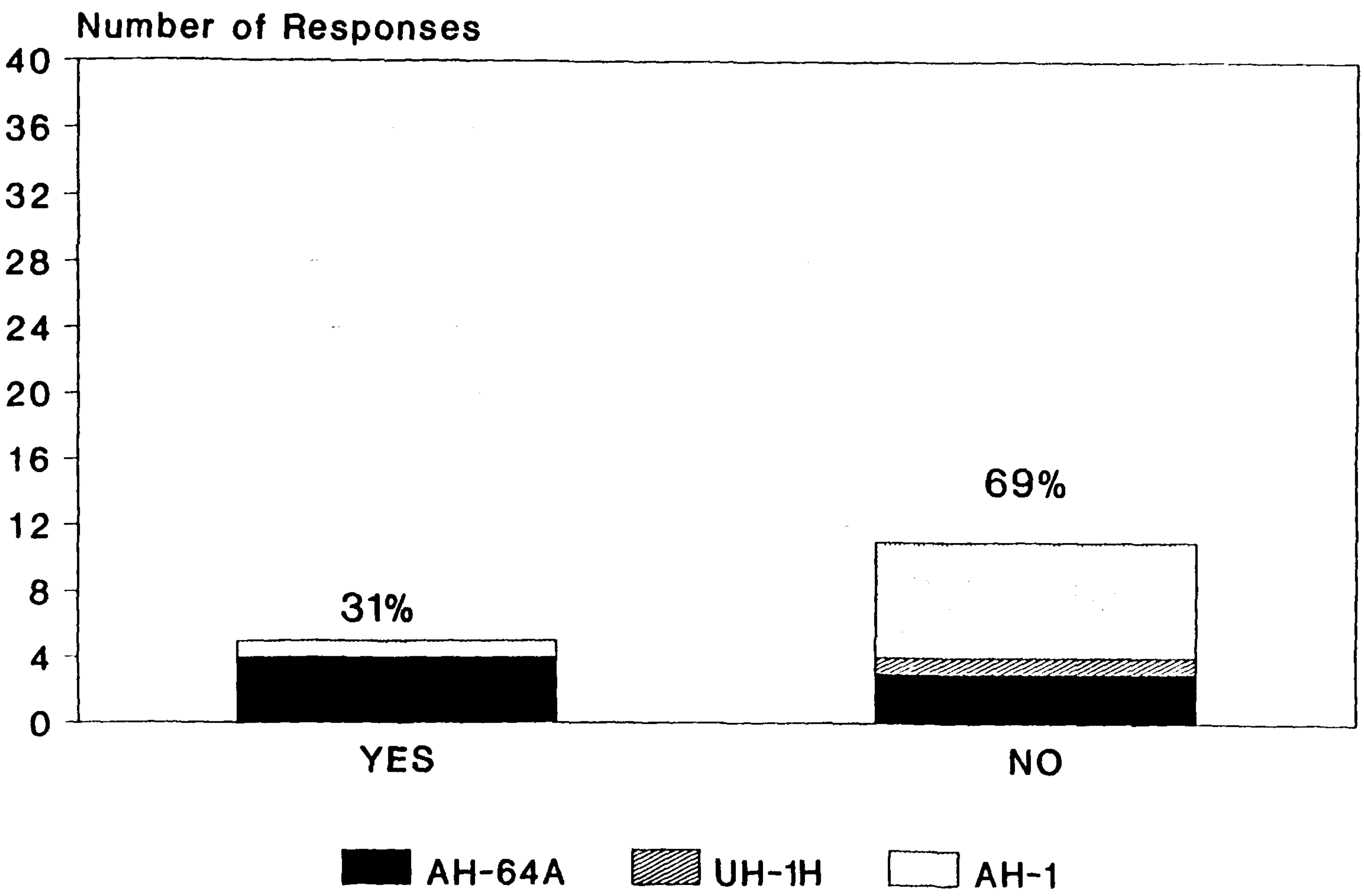
Night (N = 16)

Item 13. The CWS will help to provide a substantial reduction in helicopter wire strike accidents.



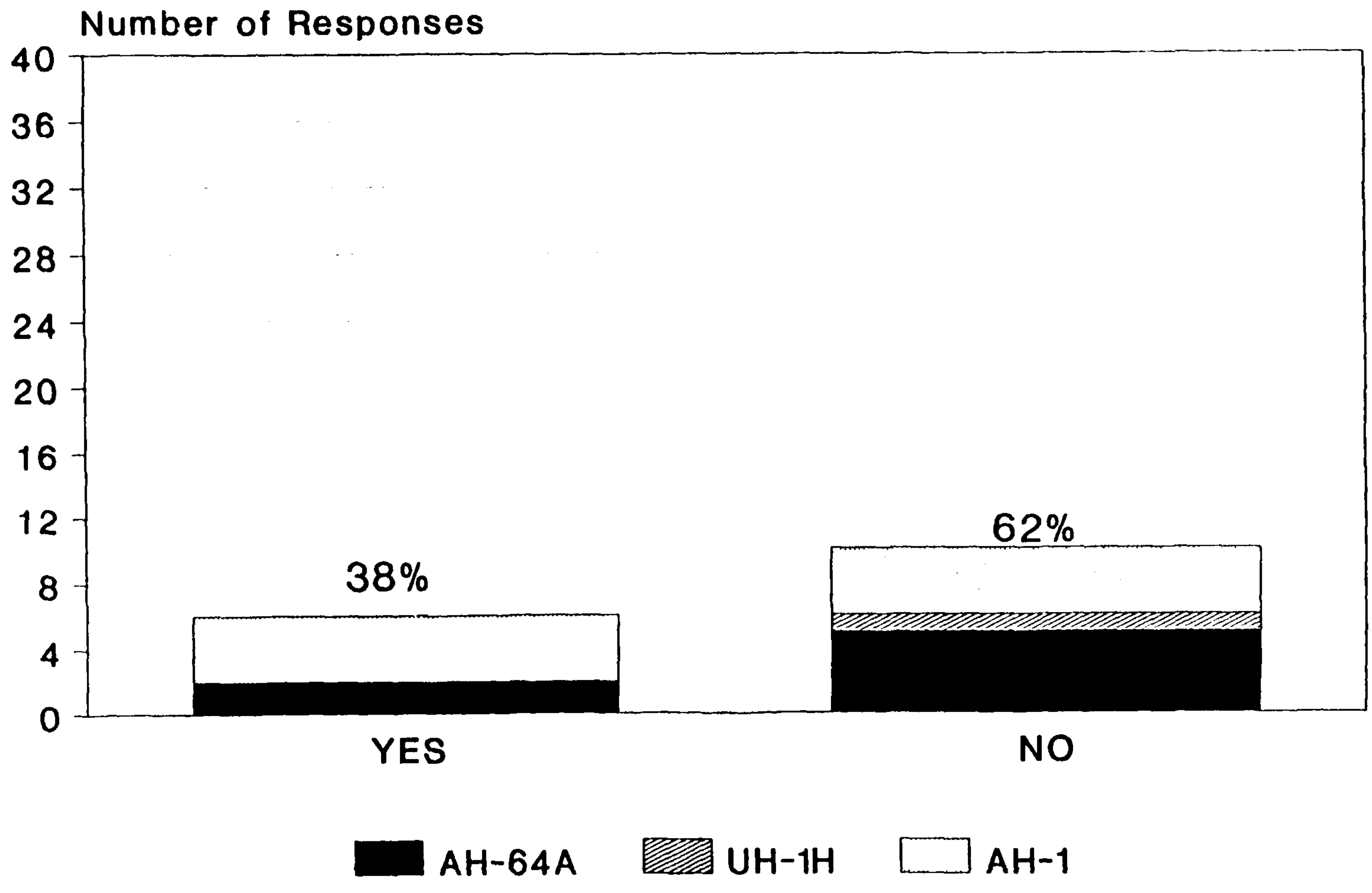
Night (N = 16)

Item 14. Is the CWS display lacking any information that is needed to make the system more effective?



Night (N = 16)

Item 15. Overall, do you believe that the CWS will help aviators avoid wire strikes?

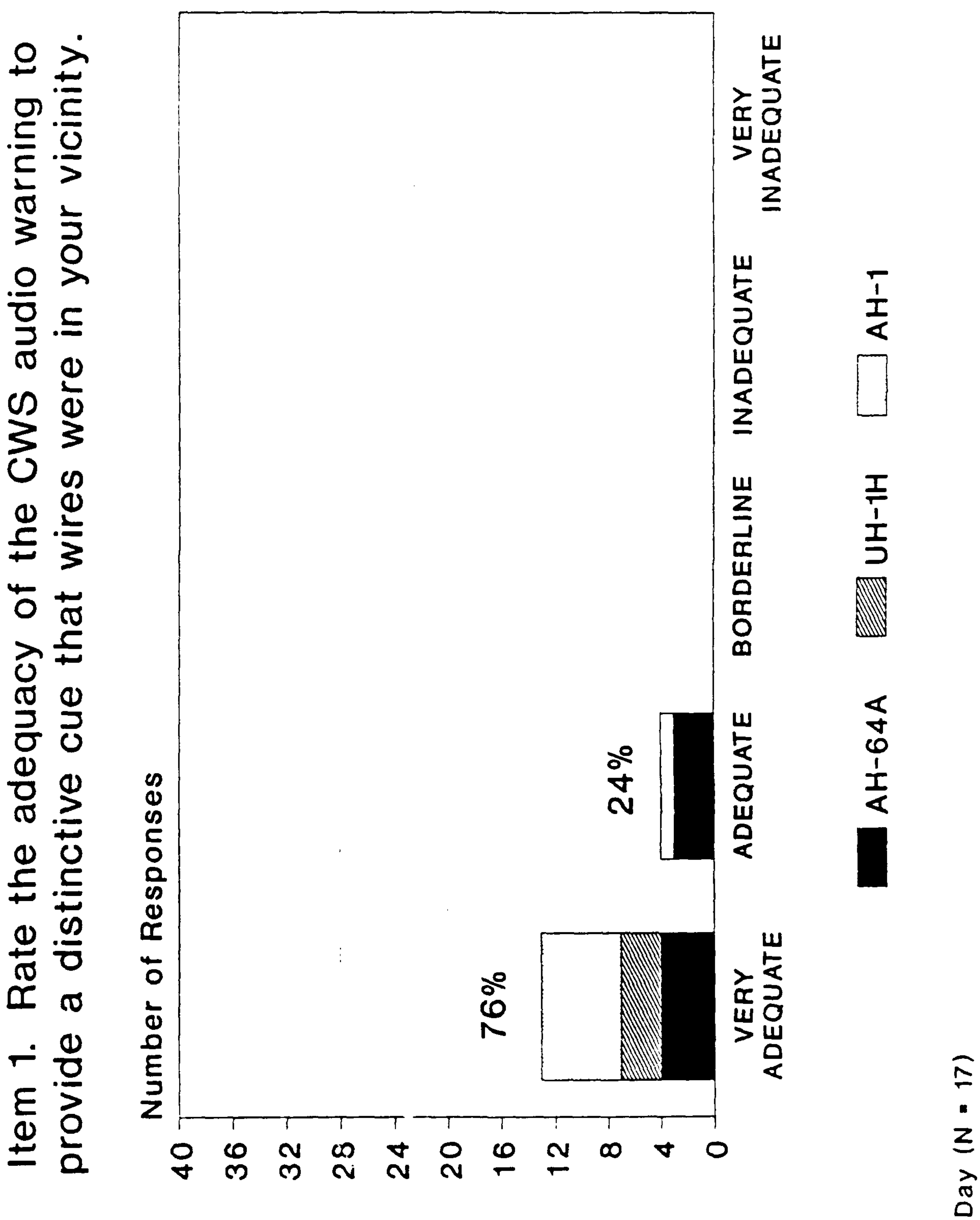


Night (N • 16)

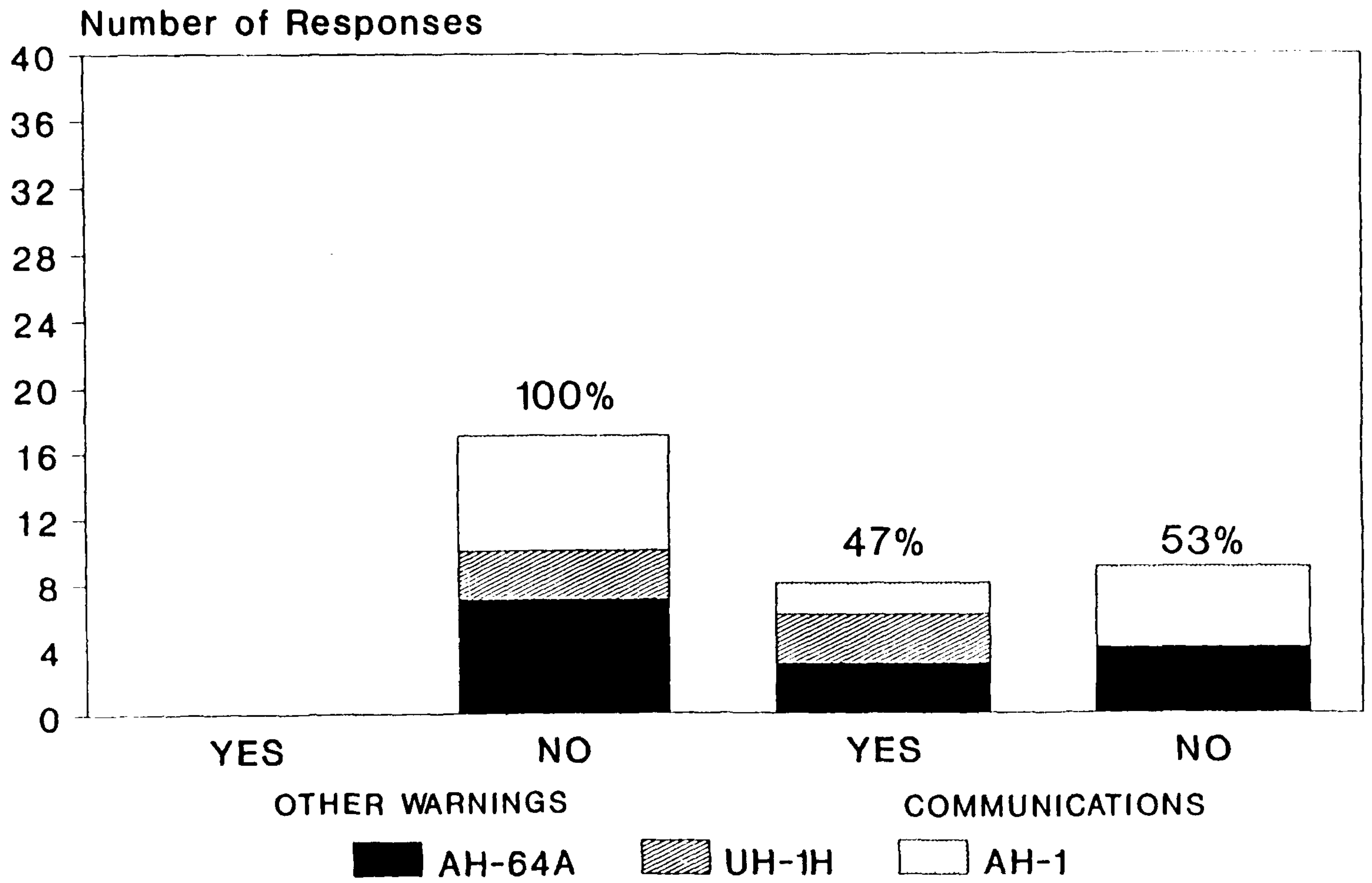
APPENDIX D

RESULTS OF CWS QUESTIONNAIRE FOR PILOTS USING CWS DURING DAYLIGHT ONLY

(17 Participants)

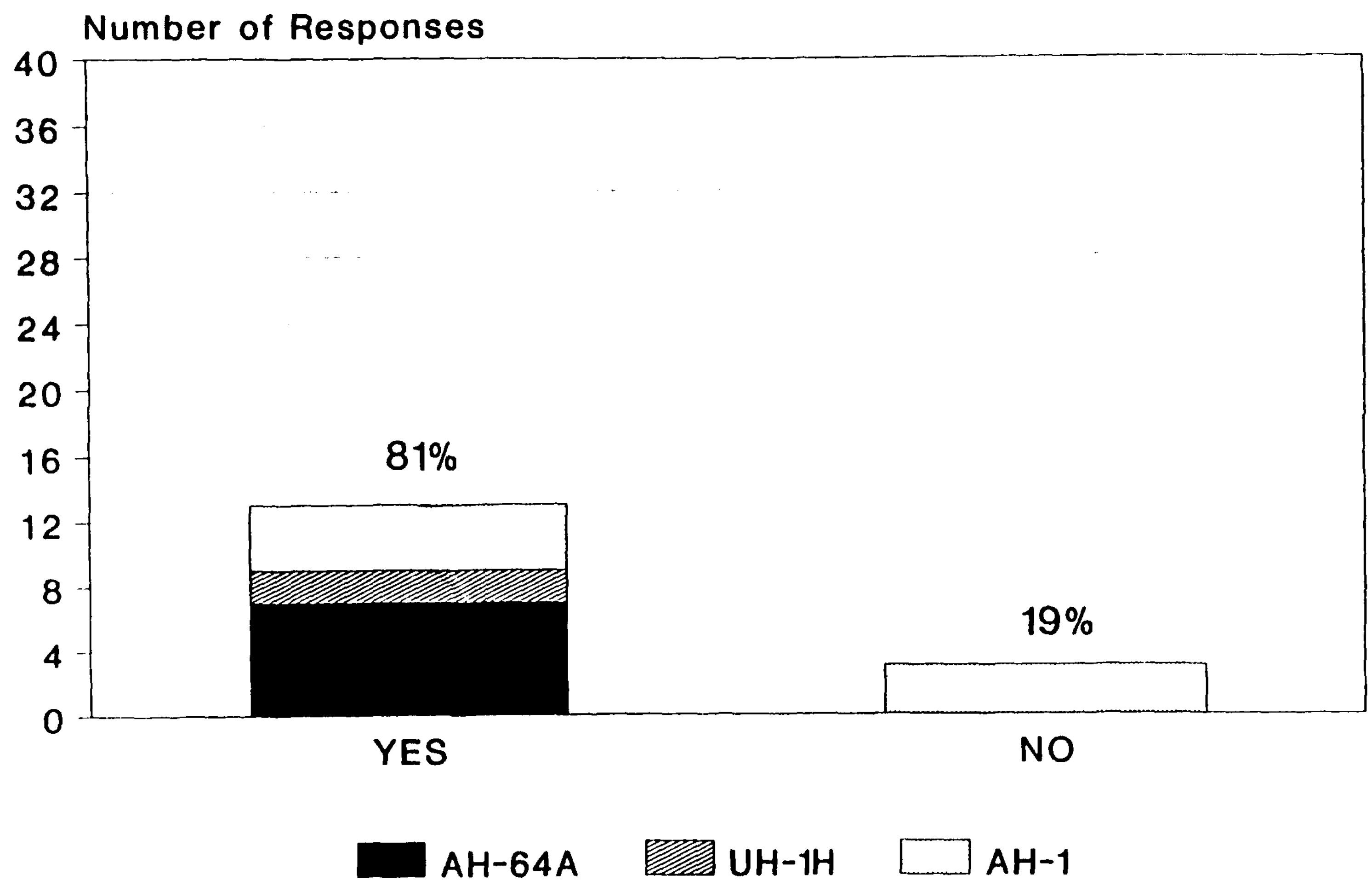


Item 2. Did the CWS audio warnings interfere with other audio warnings or with communications?



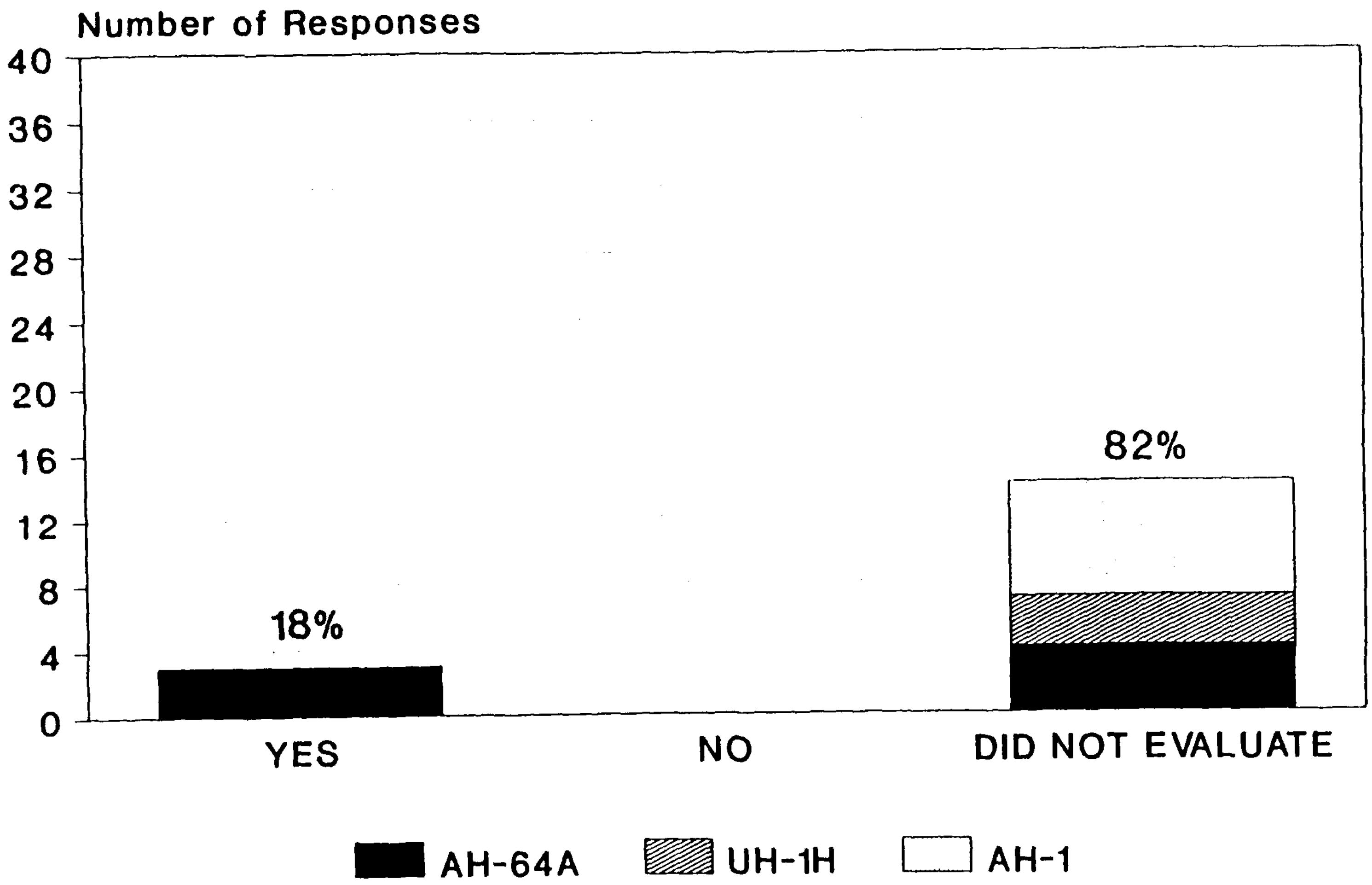
Day (N = 17)

Item 3a. Were the CWS display lights easily seen in direct sunlight?



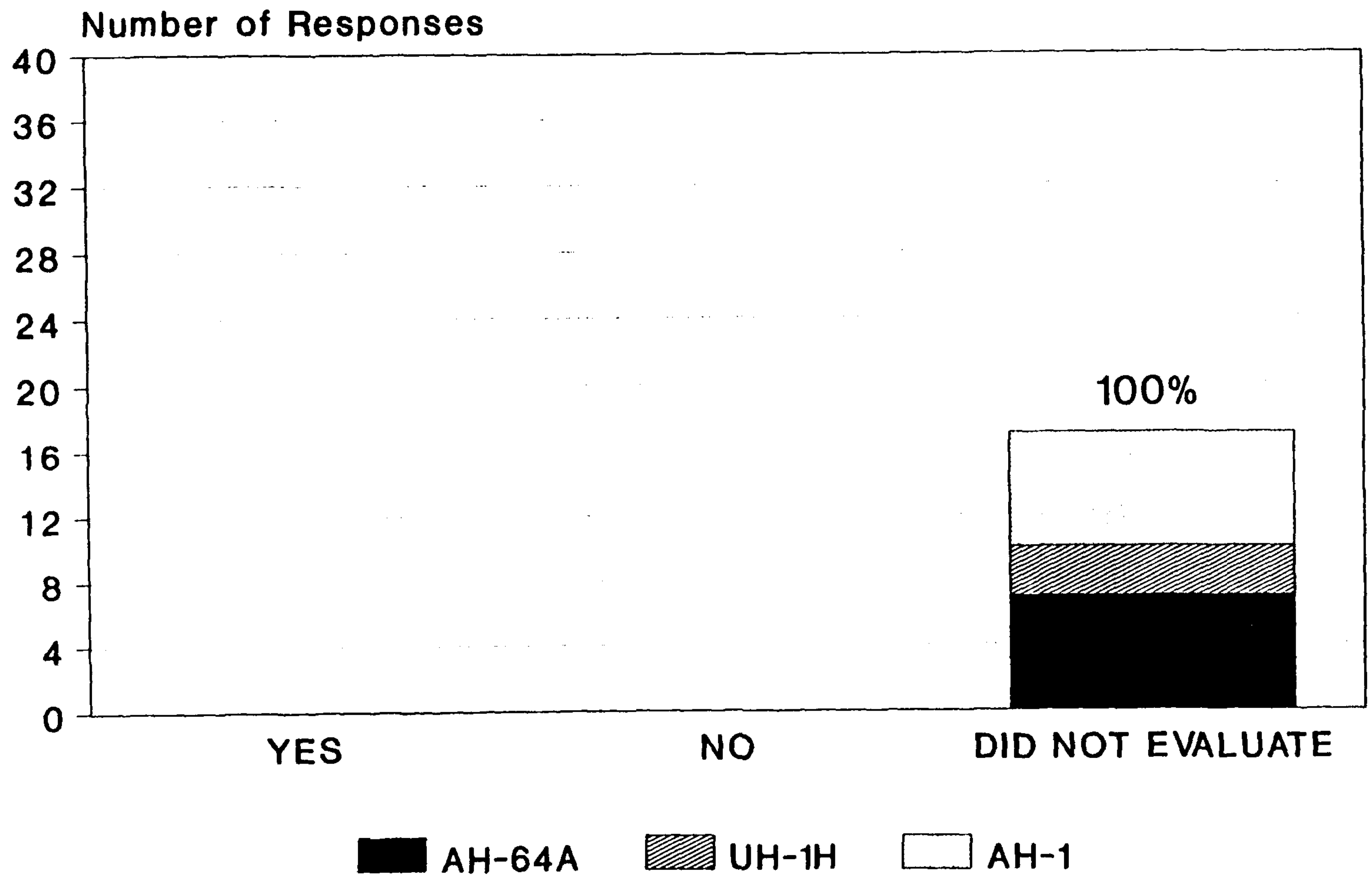
Day (N = 16)

Item 4. Was the CWS display location usable when wearing night vision goggles or the helmet mounted display?



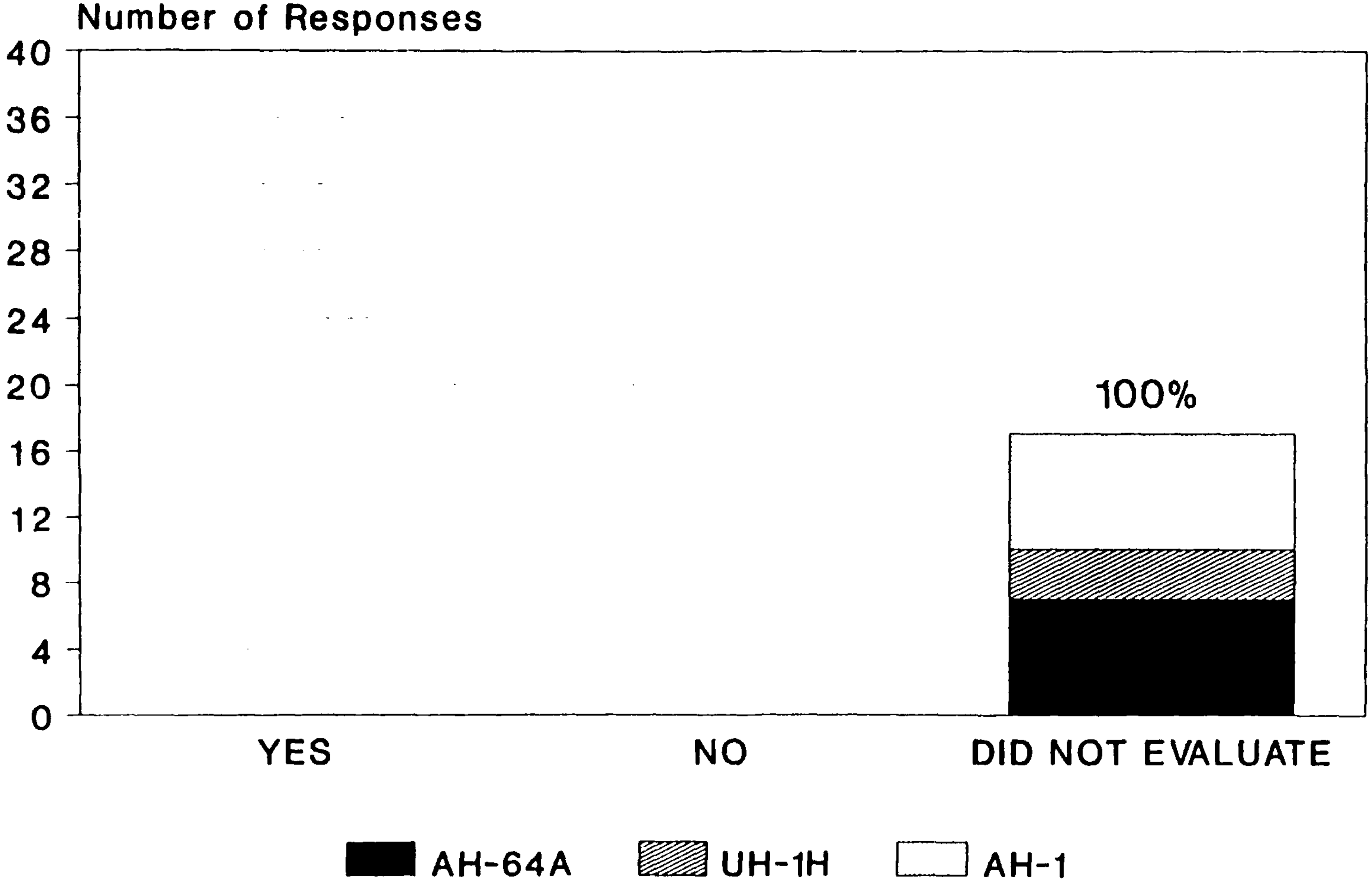
Day (N = 17)

Item 5. Were the CWS lights NVG/HMD compatible?



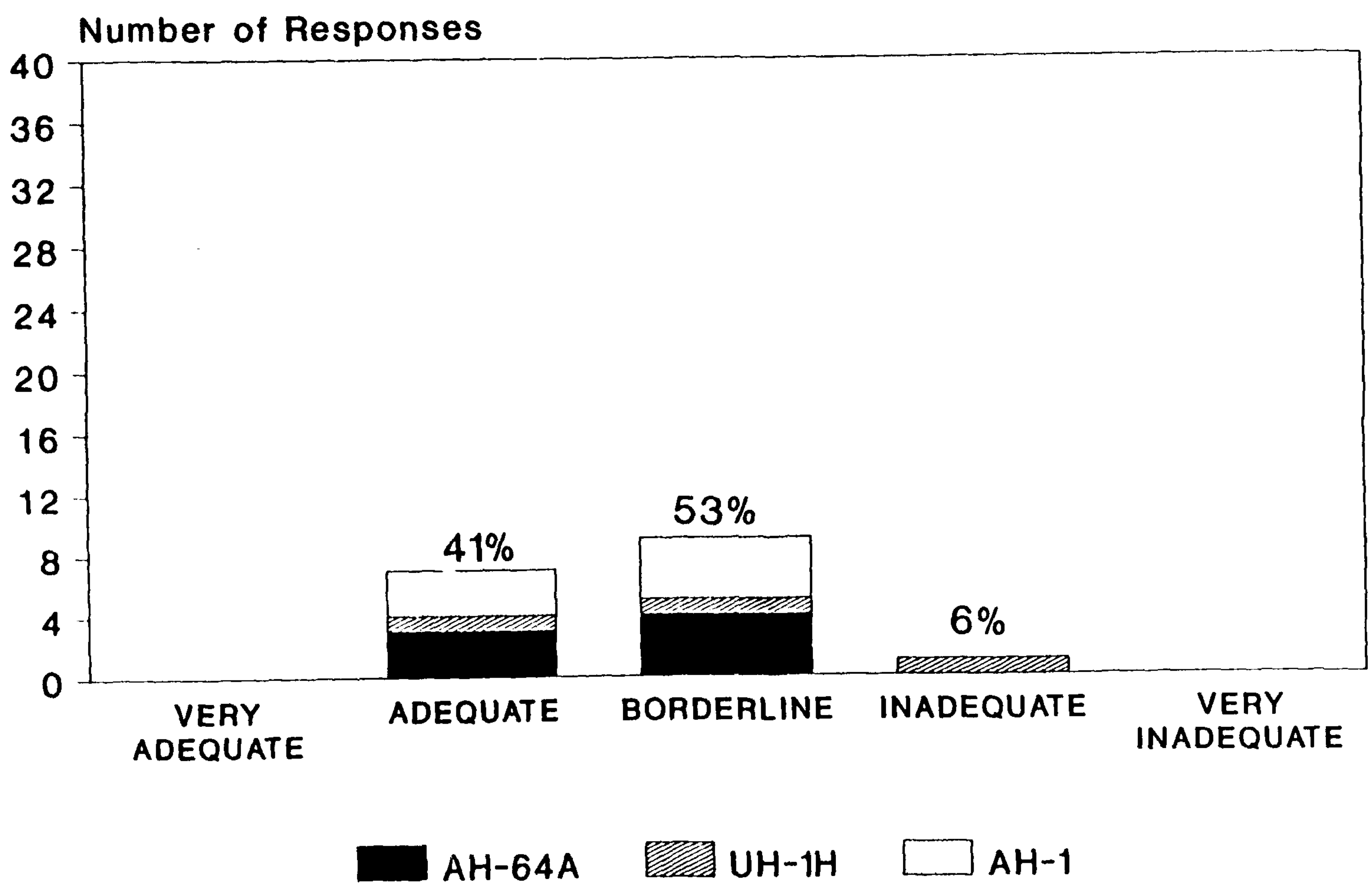
Day (N = 17)

Item 6. Were the CWS lights adequate for use during night unaided flight?



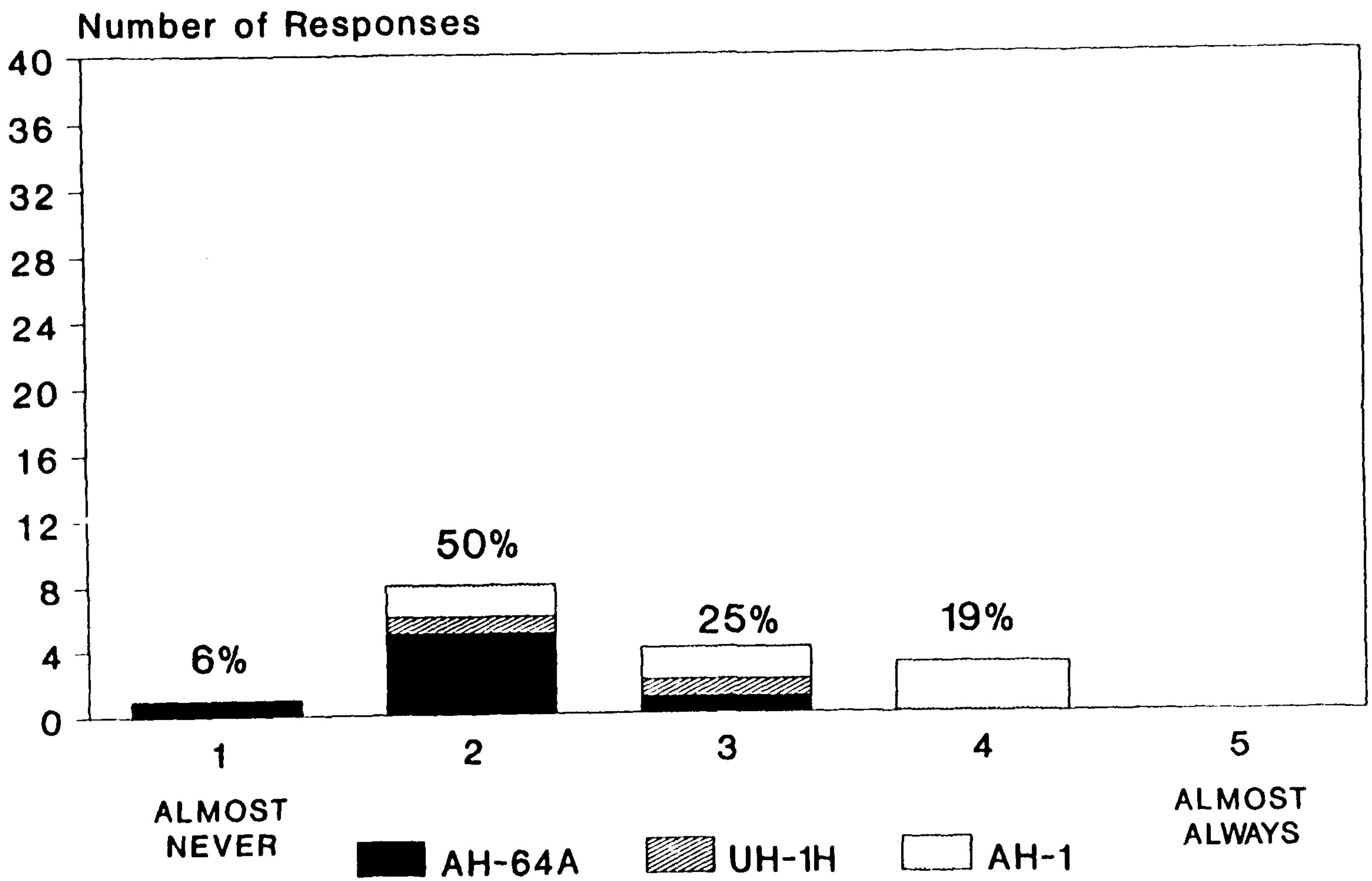
Day (N • 16)

Item 7. Did the CWS provide adequate information for you to determine the relative bearing to the wires?



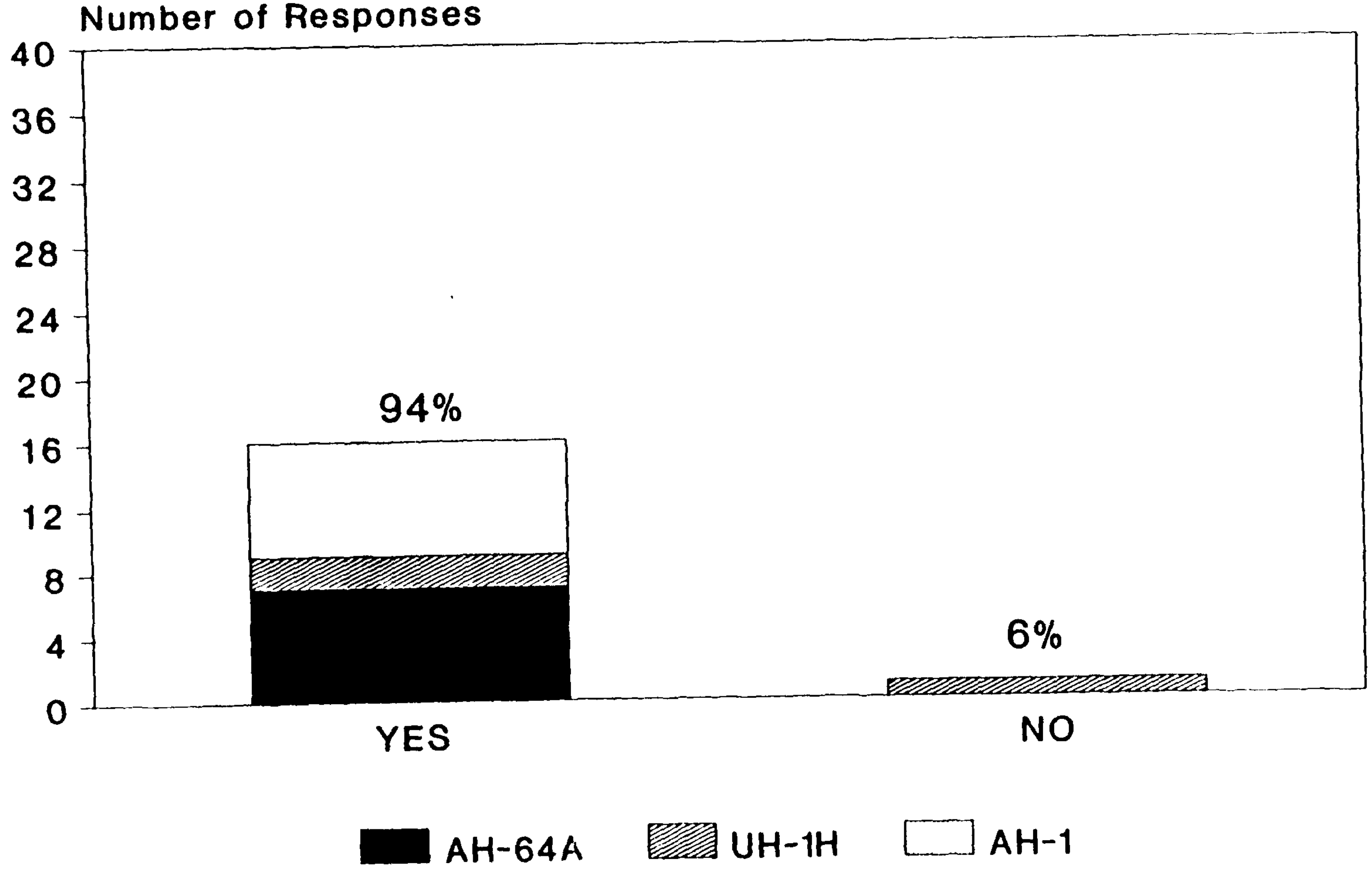
Day (N = 17)

Item 8. In general, did the CWS warn you of the presence of wires in sufficient time to successfully perform an avoidance maneuver?



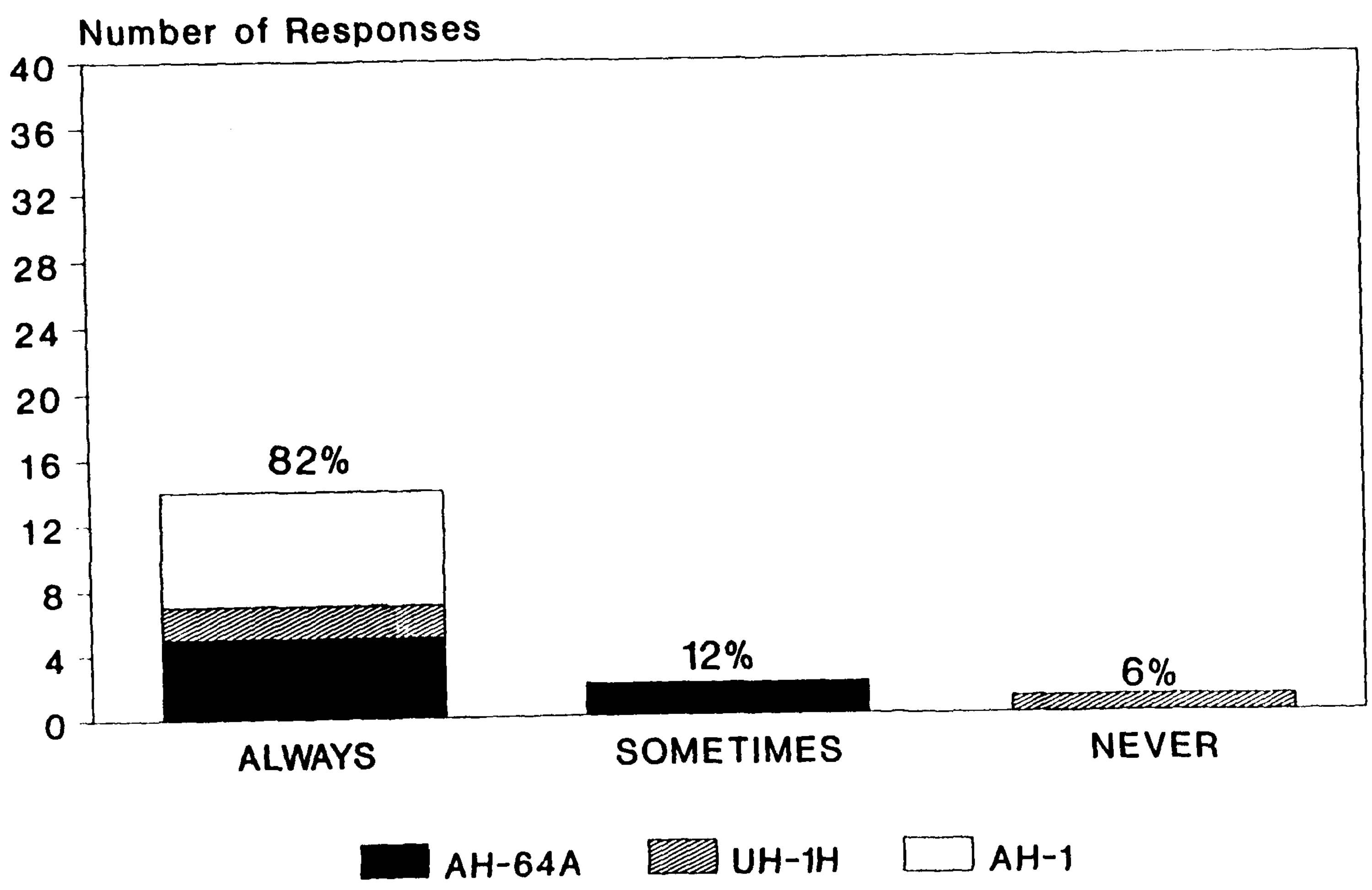
Day (N = 16)

Item 9. Was there ever a case where CWS did not warn you in time to successfully perform an avoidance maneuver?



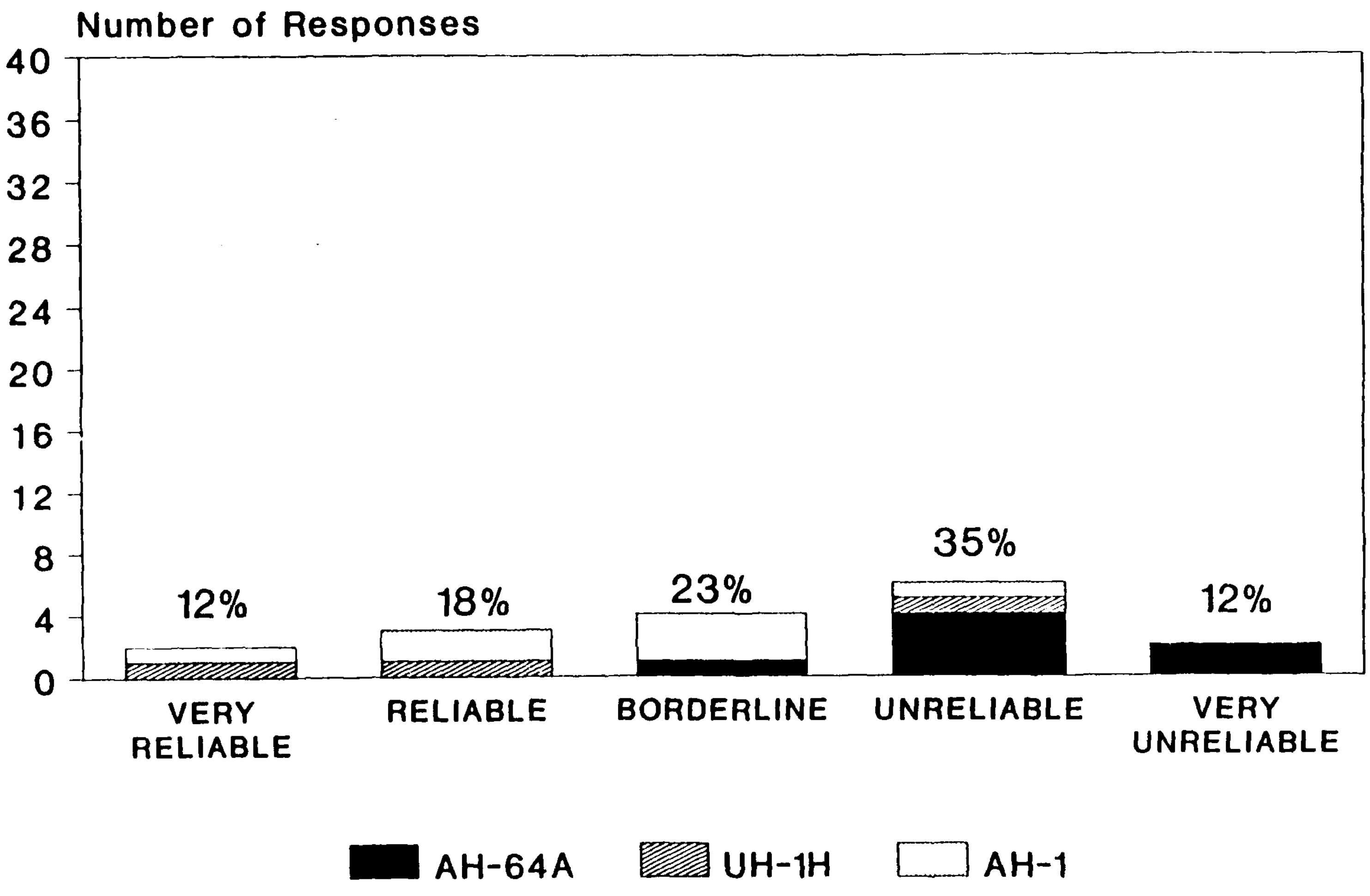
Day (N = 17)

Item 10. When CWS indicated that wires were in the vicinity, did you visually verify the presence/location of the wires before starting an evasive maneuver?



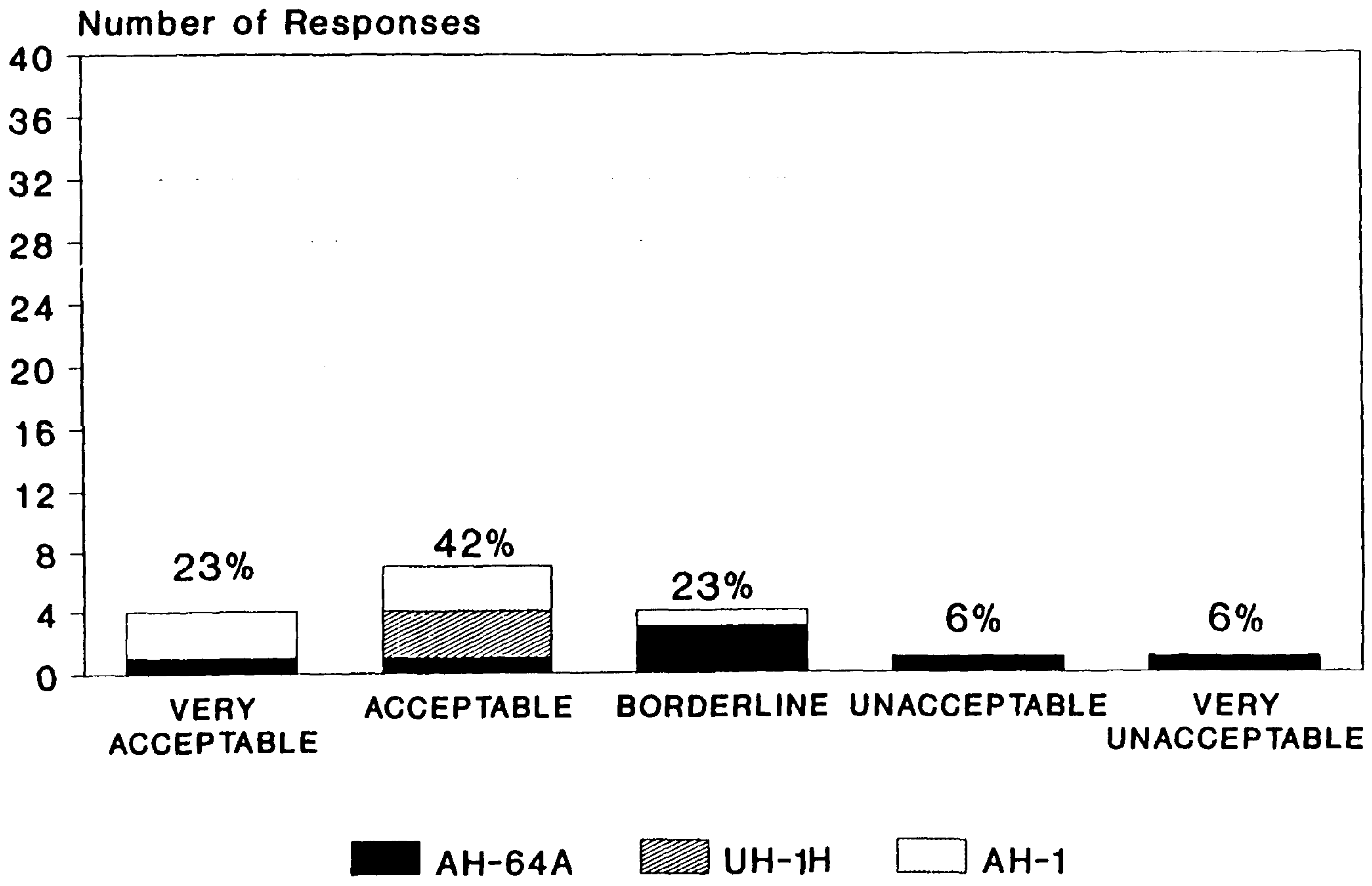
Day (N = 17)

Item 11. Was the CWS a reliable indicator that wires were in the vicinity (that is, when a wire is present, did the CWS provide an indication)?



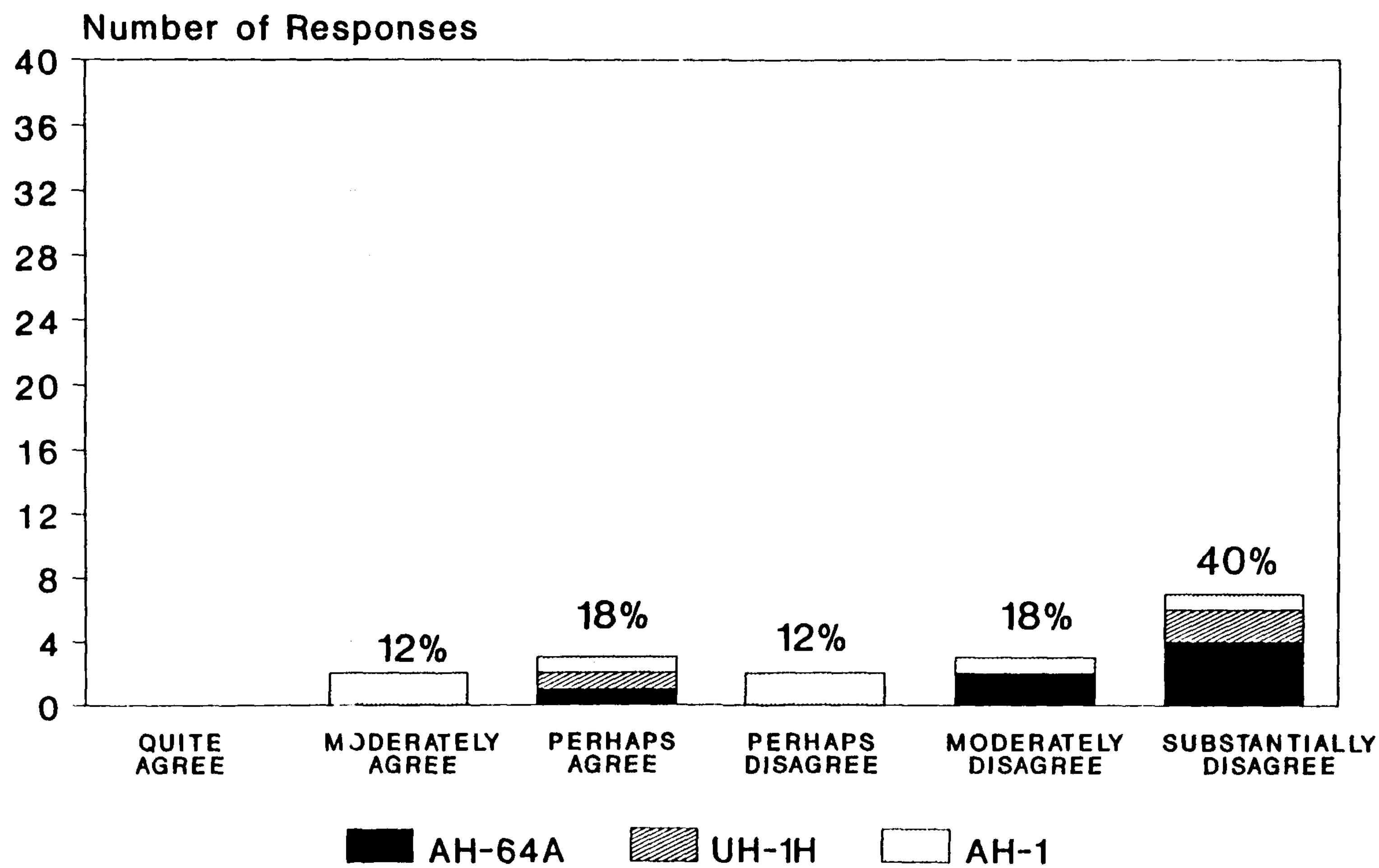
Day (N = 17)

Item 12. Evaluate the false alarm rate of the CWS (a false alarm is when the CWS indicates wires are present, but no wires are in the vicinity).



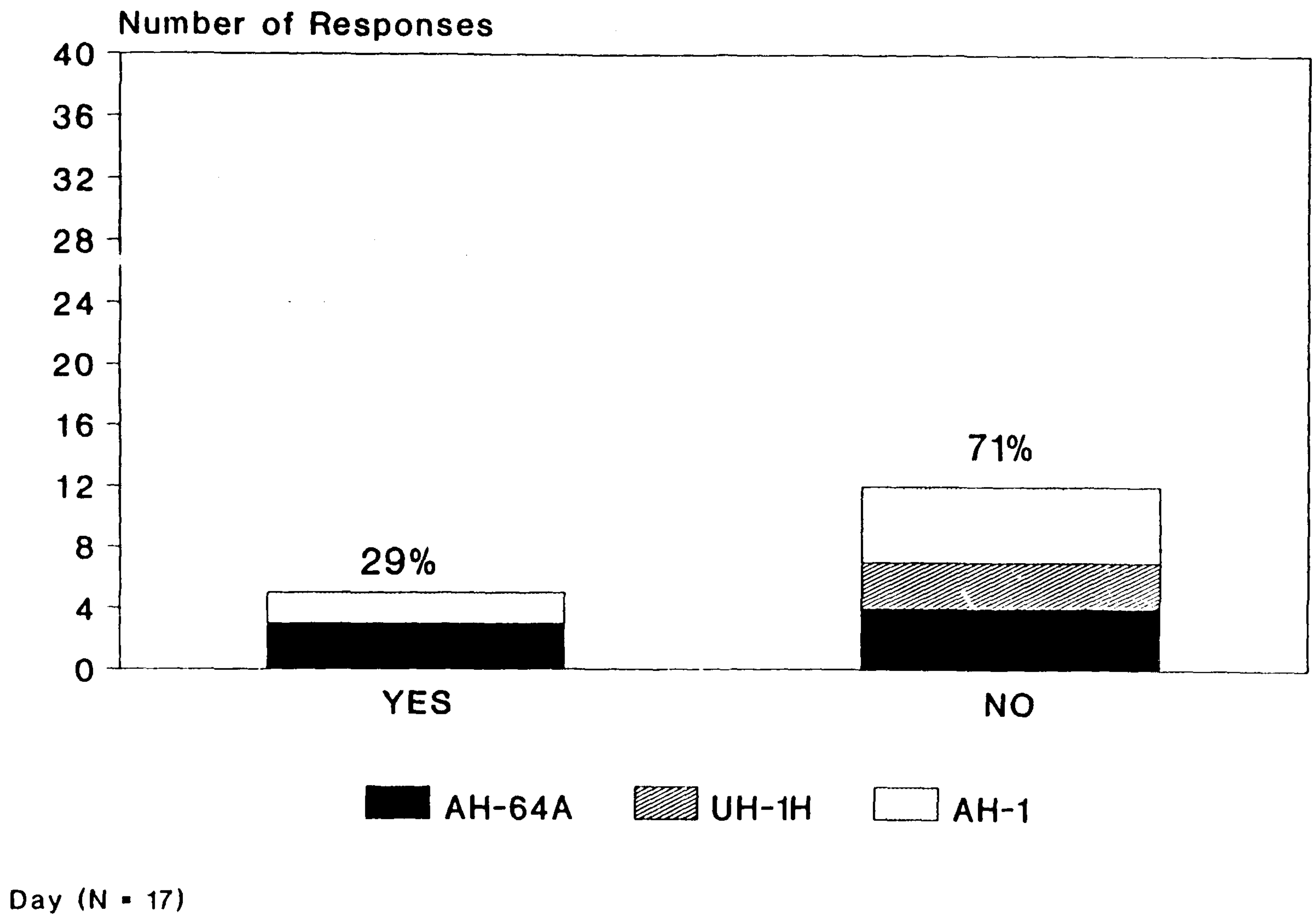
Day (N = 17)

Item 13. The CWS will help to provide a substantial reduction in helicopter wire strike accidents.

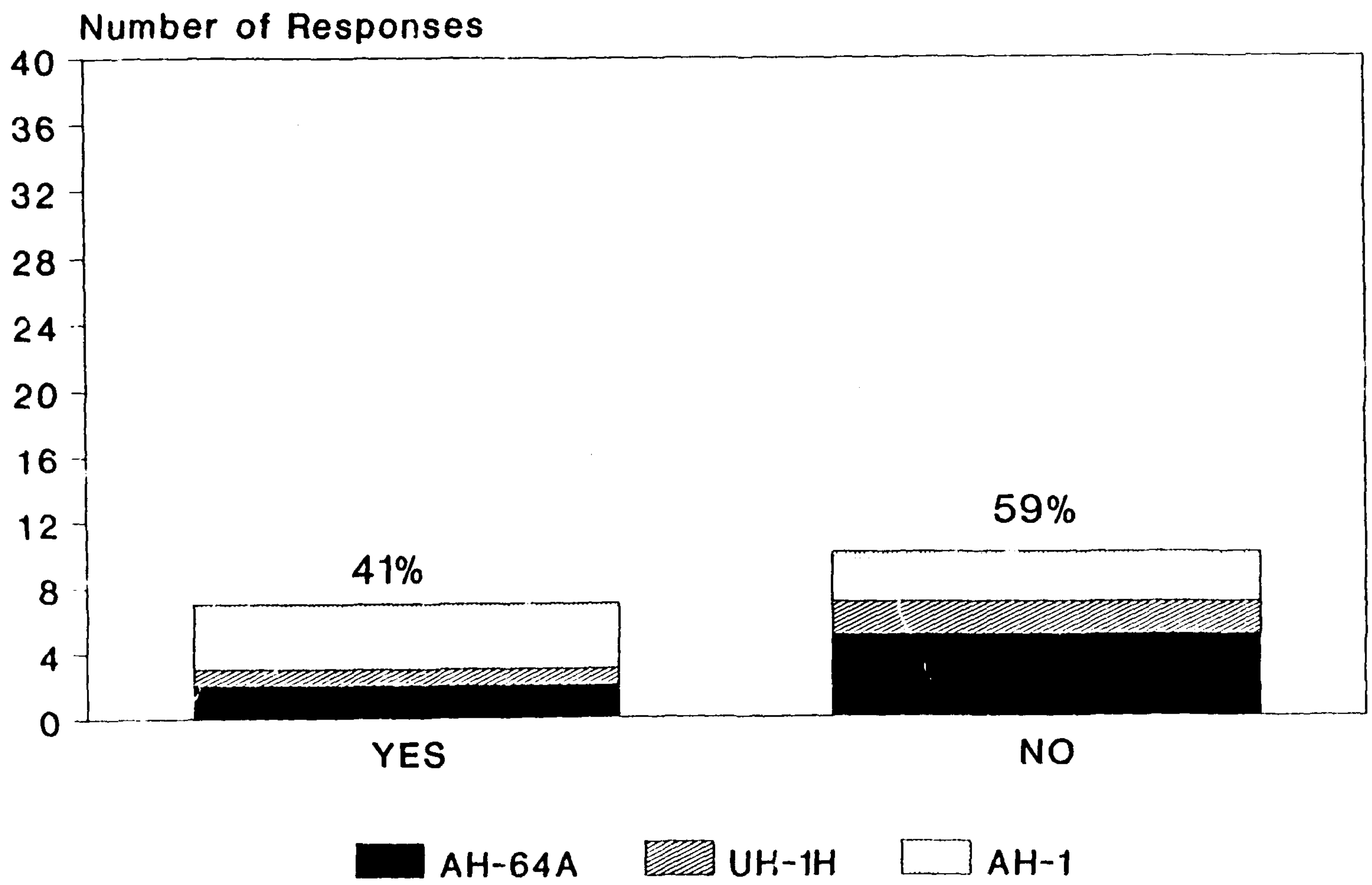


Day (N = 17)

Item 14. Is the CWS display lacking any information that is needed to make the system more effective?



Item 15. Overall, do you believe that the CWS will help aviators avoid wire strikes?

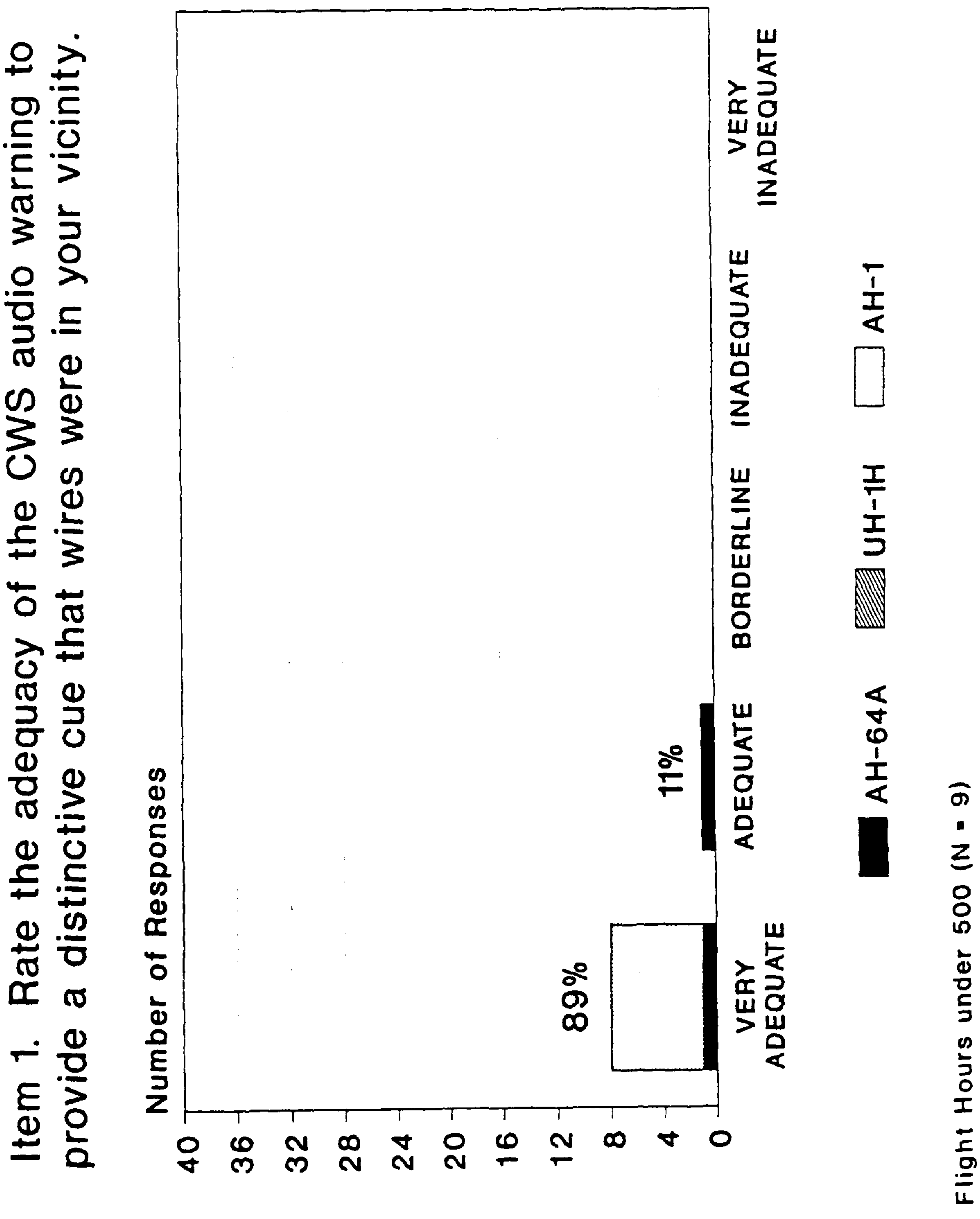


Day (N = 17)

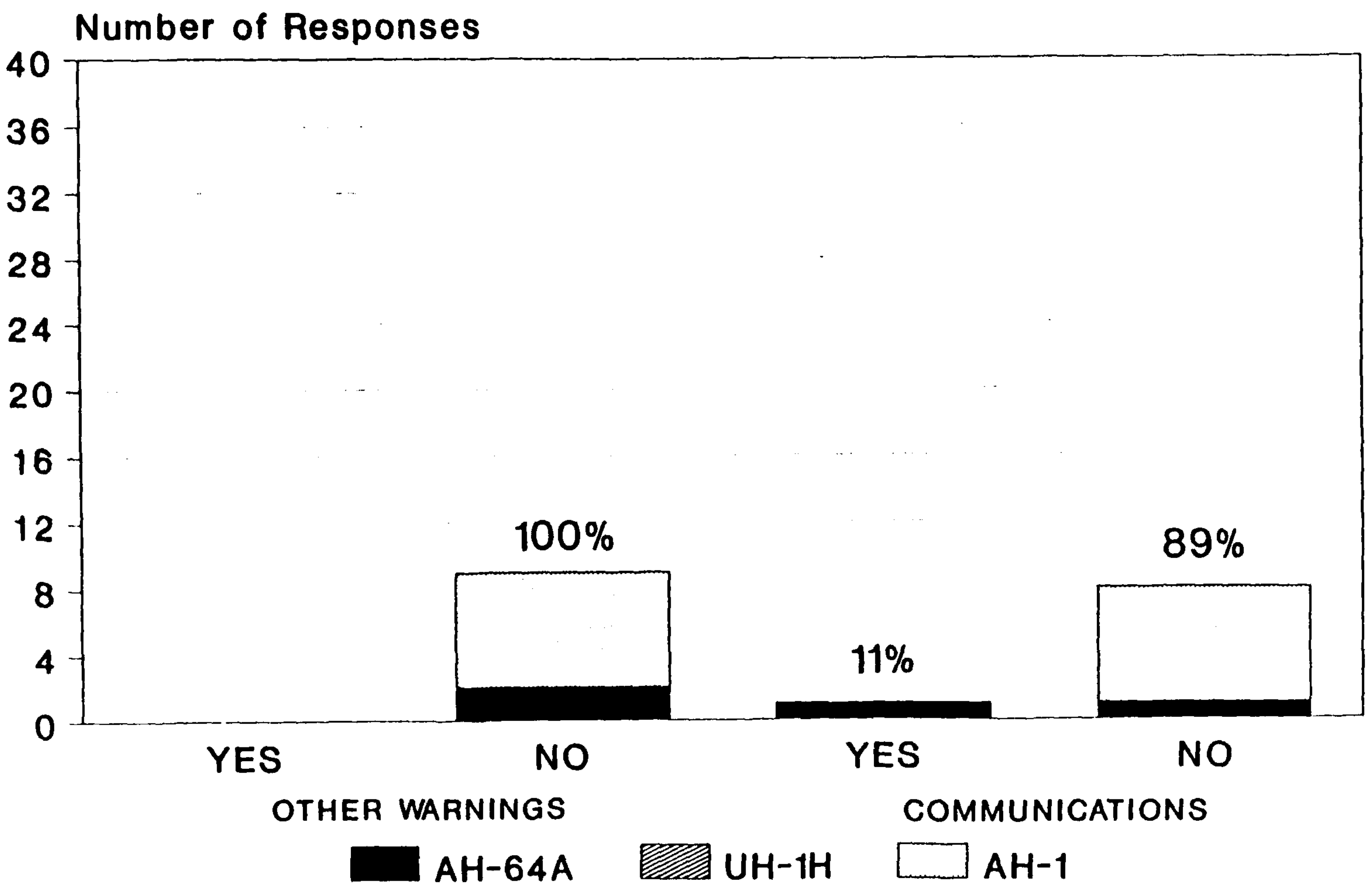
APPENDIX E

<u>RESULTS OF CWS QUESTIONNAIRE FOR PILOTS HAVING TOTAL FLIGHT HOURS OF 500 OR LESS</u>

(9 Participants)

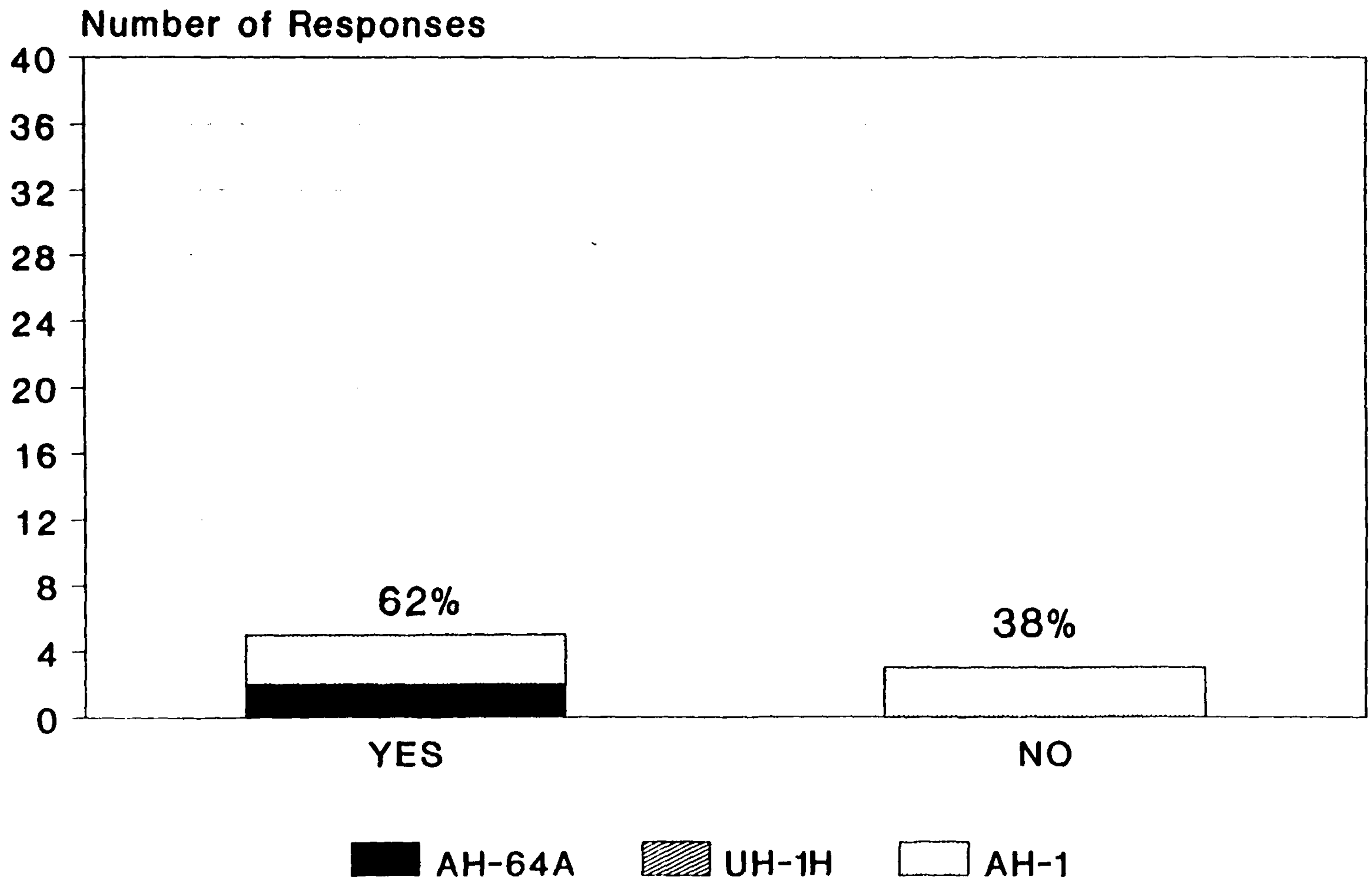


Item 2. Did the CWS audio warnings interfere with other audio warnings or with communications?



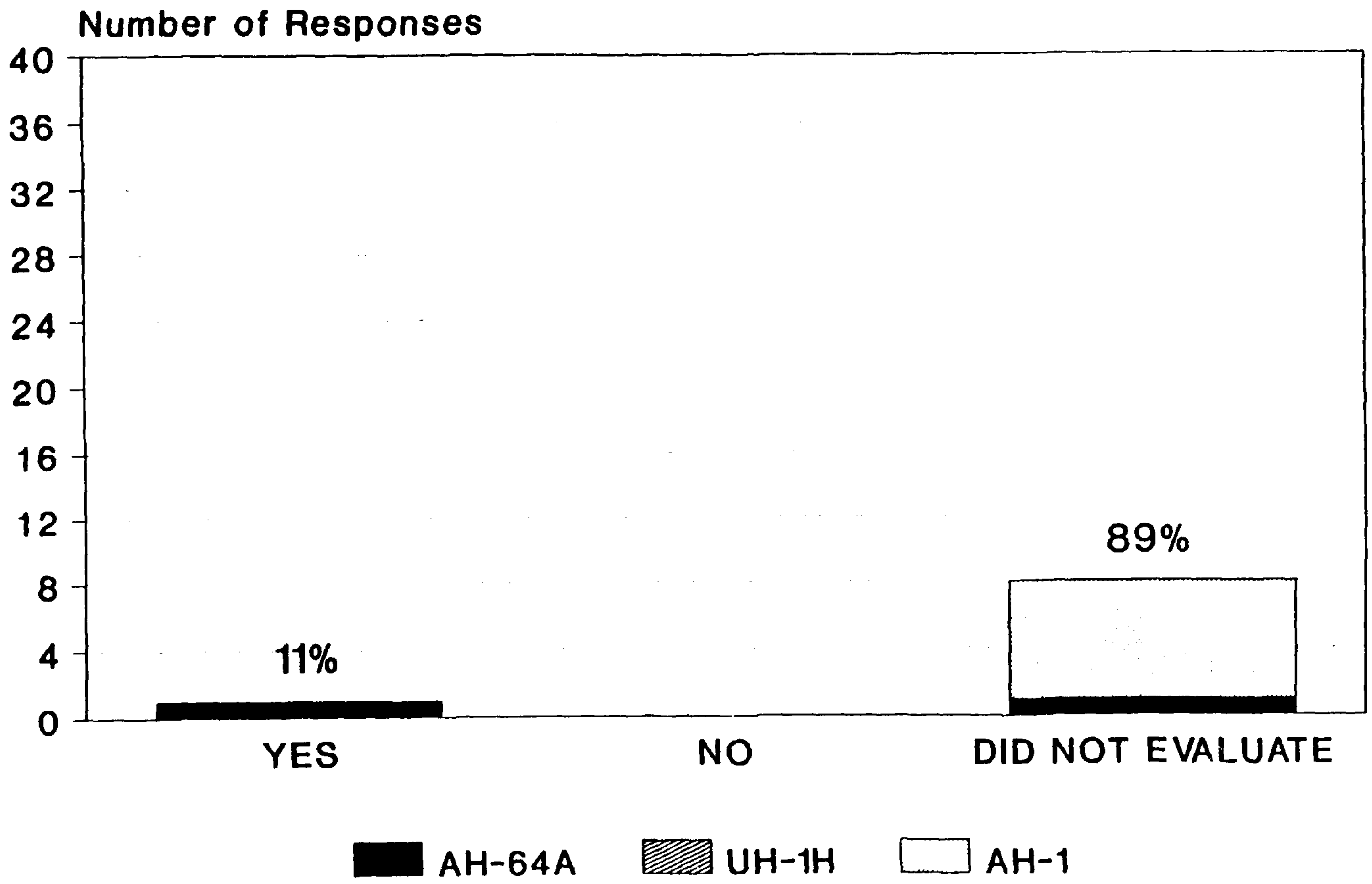
Flight Hours under 500 (N = 9)

Item 3a. Were the CWS display lights easily seen in direct sunlight?



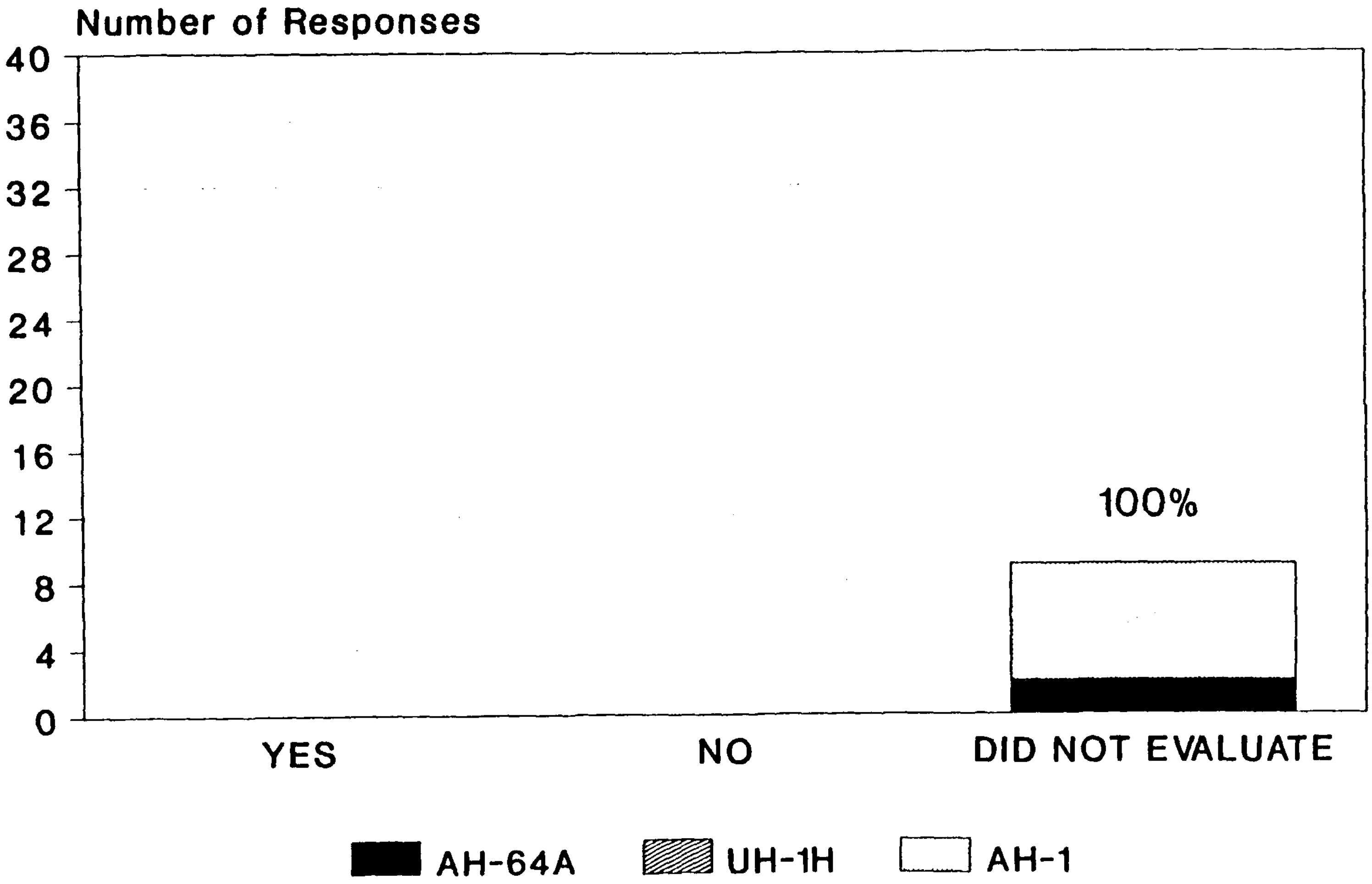
Flight Hours under 500 (N = 8)

Item 4. Was the CWS display location usable when wearing night vision goggles or the helmet mounted display?



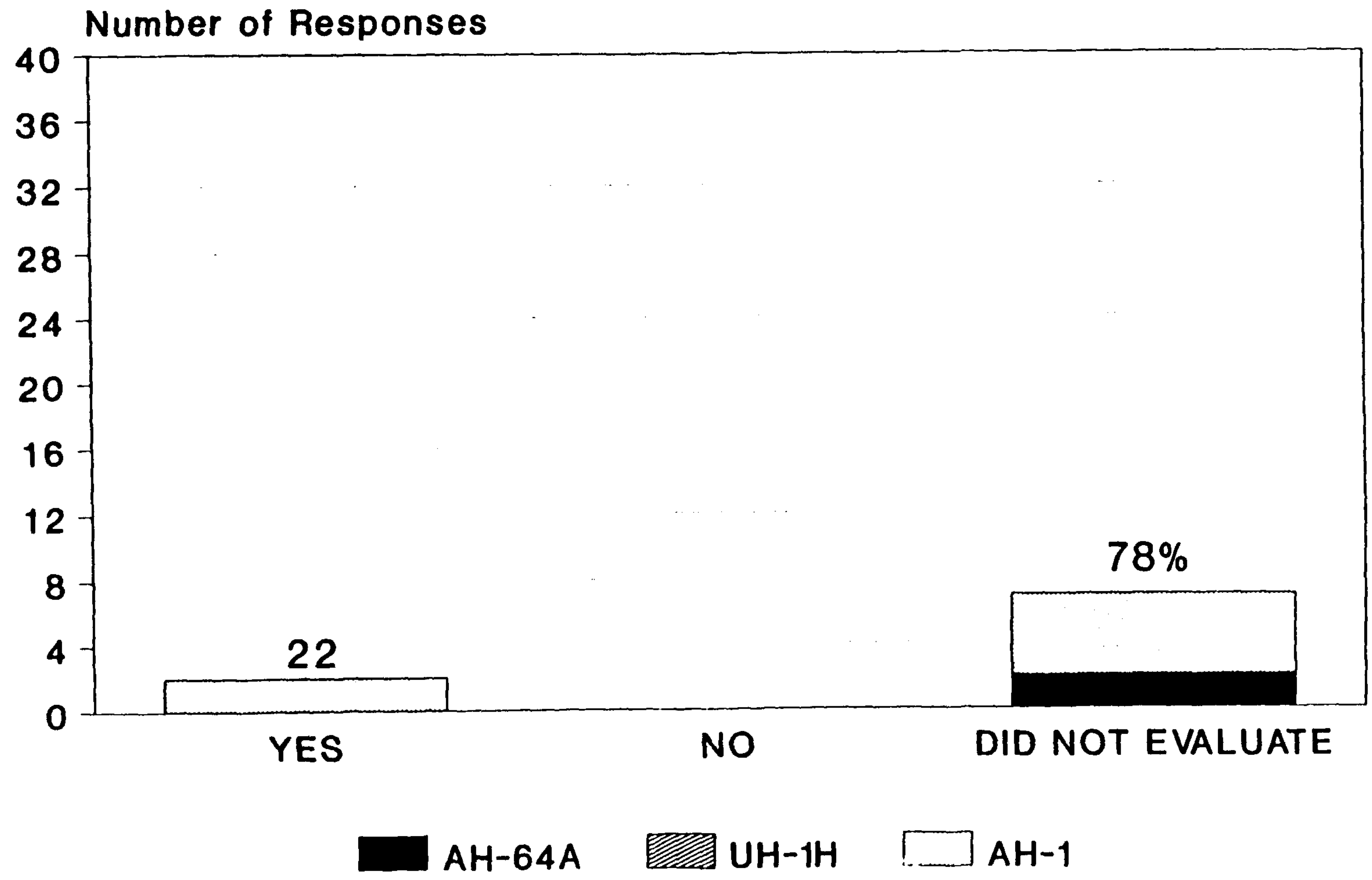
Flight Hours under 500 (N = 9)

Item 5. Were the CWS lights NVG/HMD compatible?



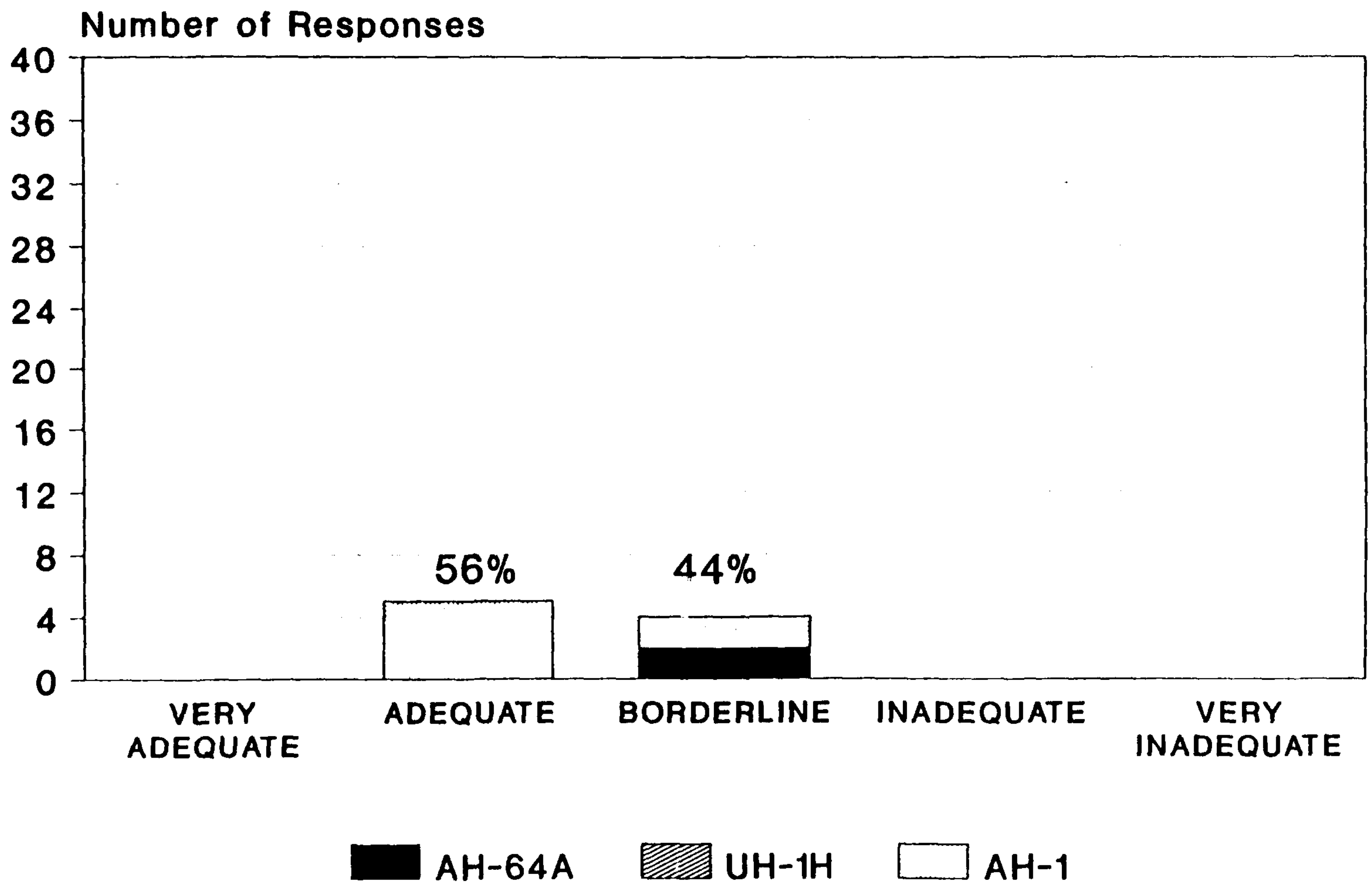
Flight Hours under 500 (N = 9)

Item 6. Were the CWS lights adequate for use during night unaided flight?



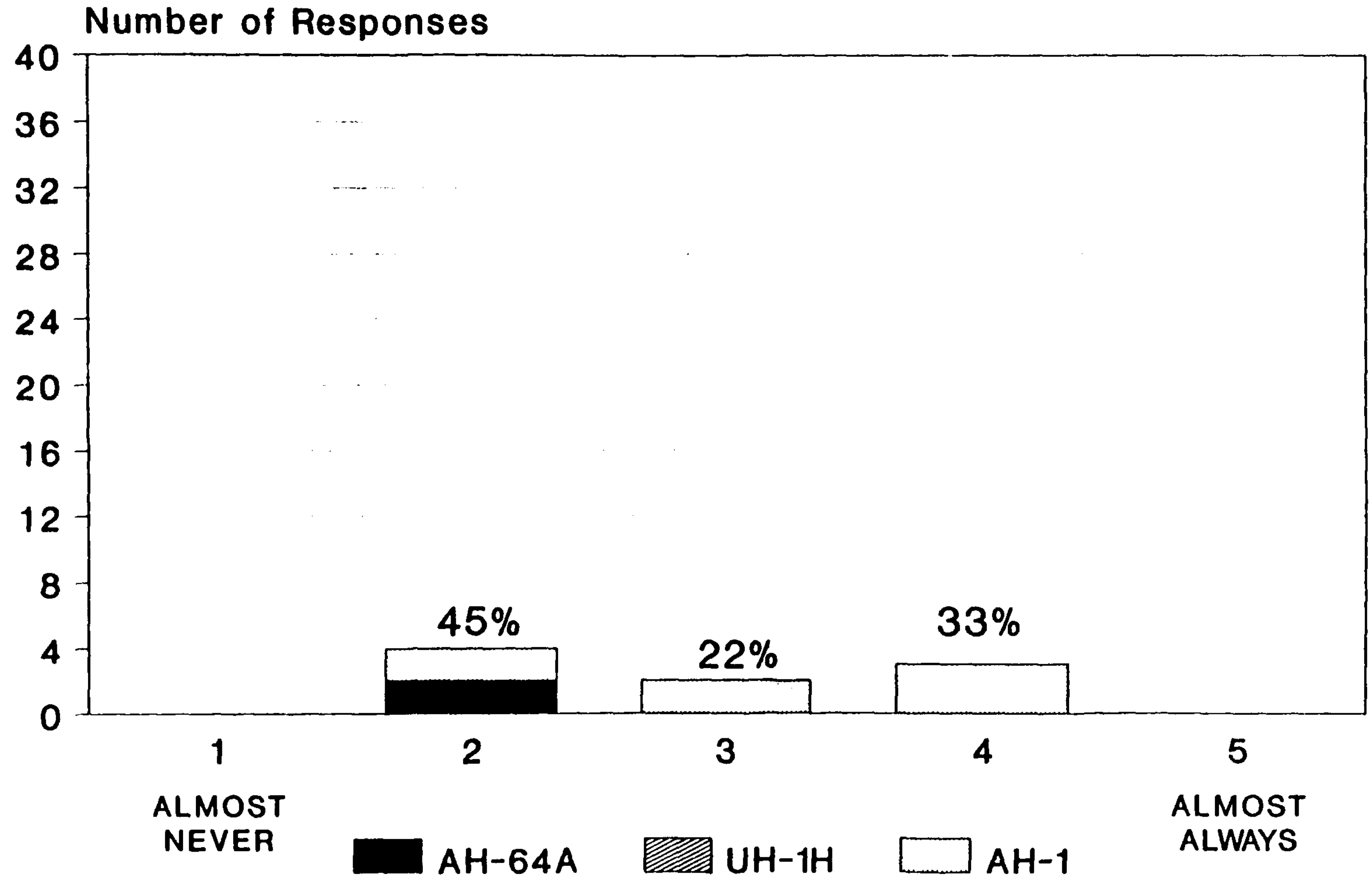
Flight Hours under 500 (N = 9)

Item 7. Did the CWS provide adequate information for you to determine the relative bearing to the wires?



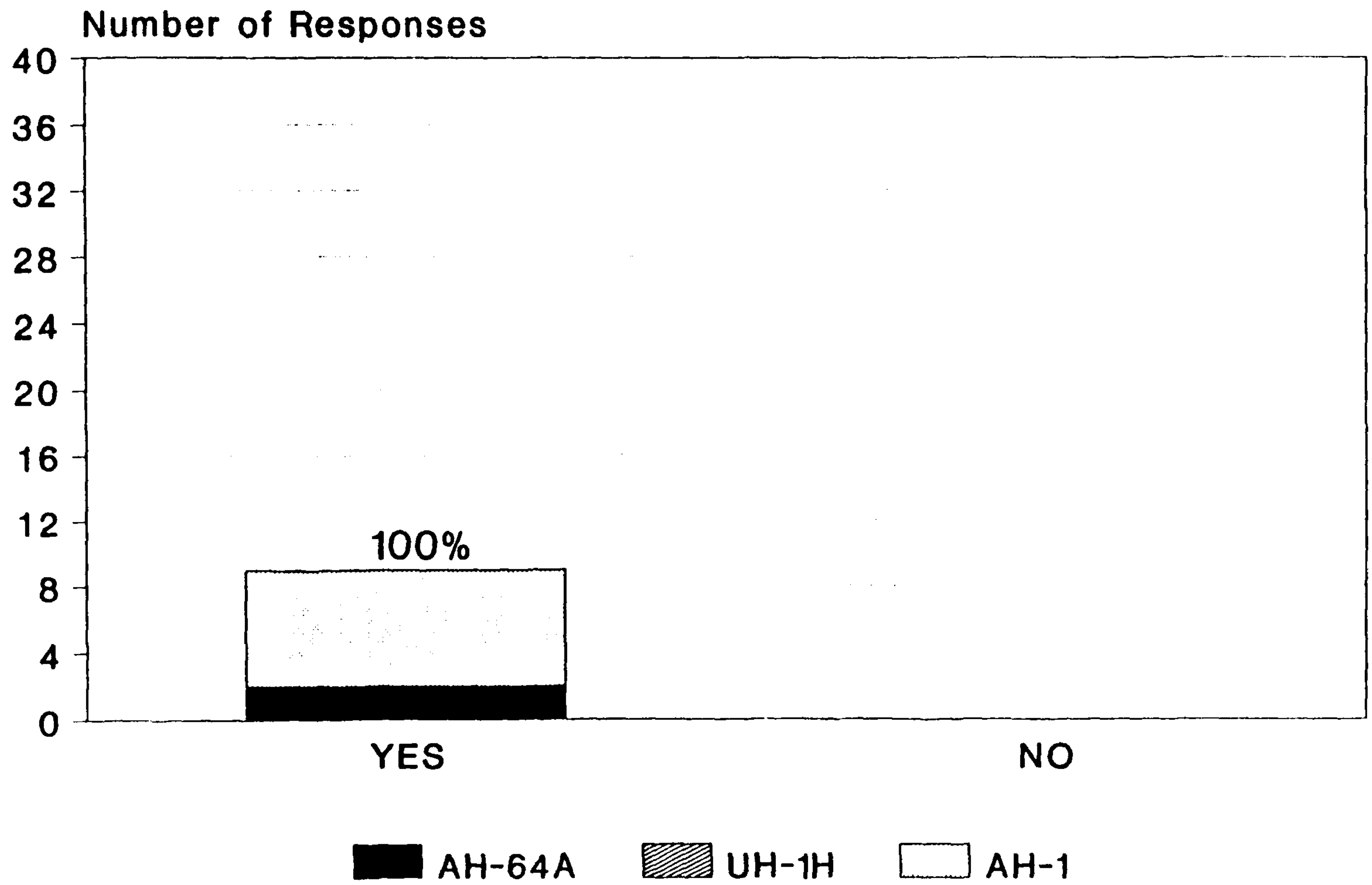
Flight Hours under 500 (N = 9)

Item 8. In general, did the CWS warn you of the presence of wires in sufficient time to successfully perform an avoidance maneuver?



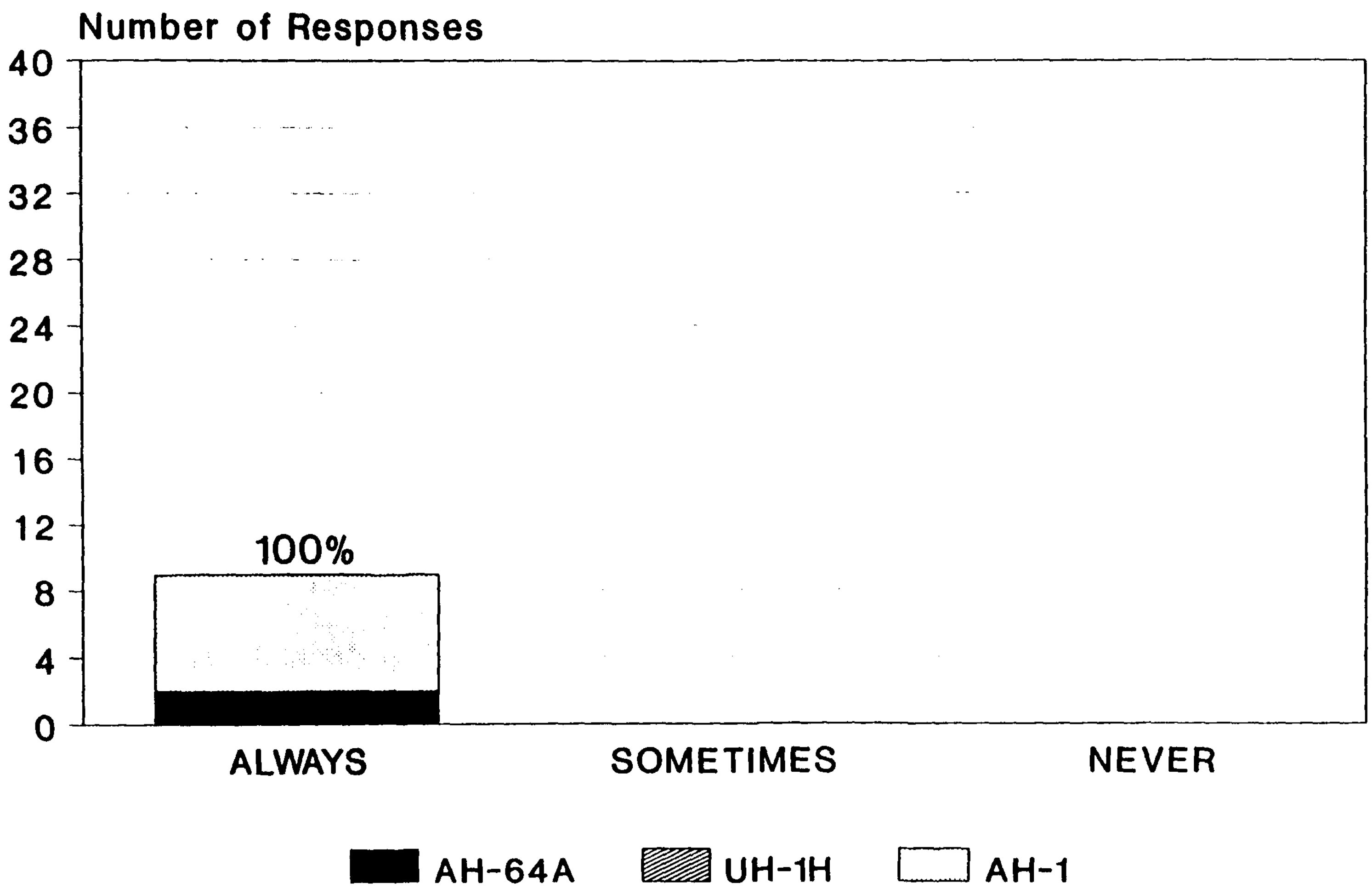
Flight Hours under 500 (N = 9)

Item 9. Was there ever a case where CWS did not warn you in time to successfully perform an avoidance maneuver?



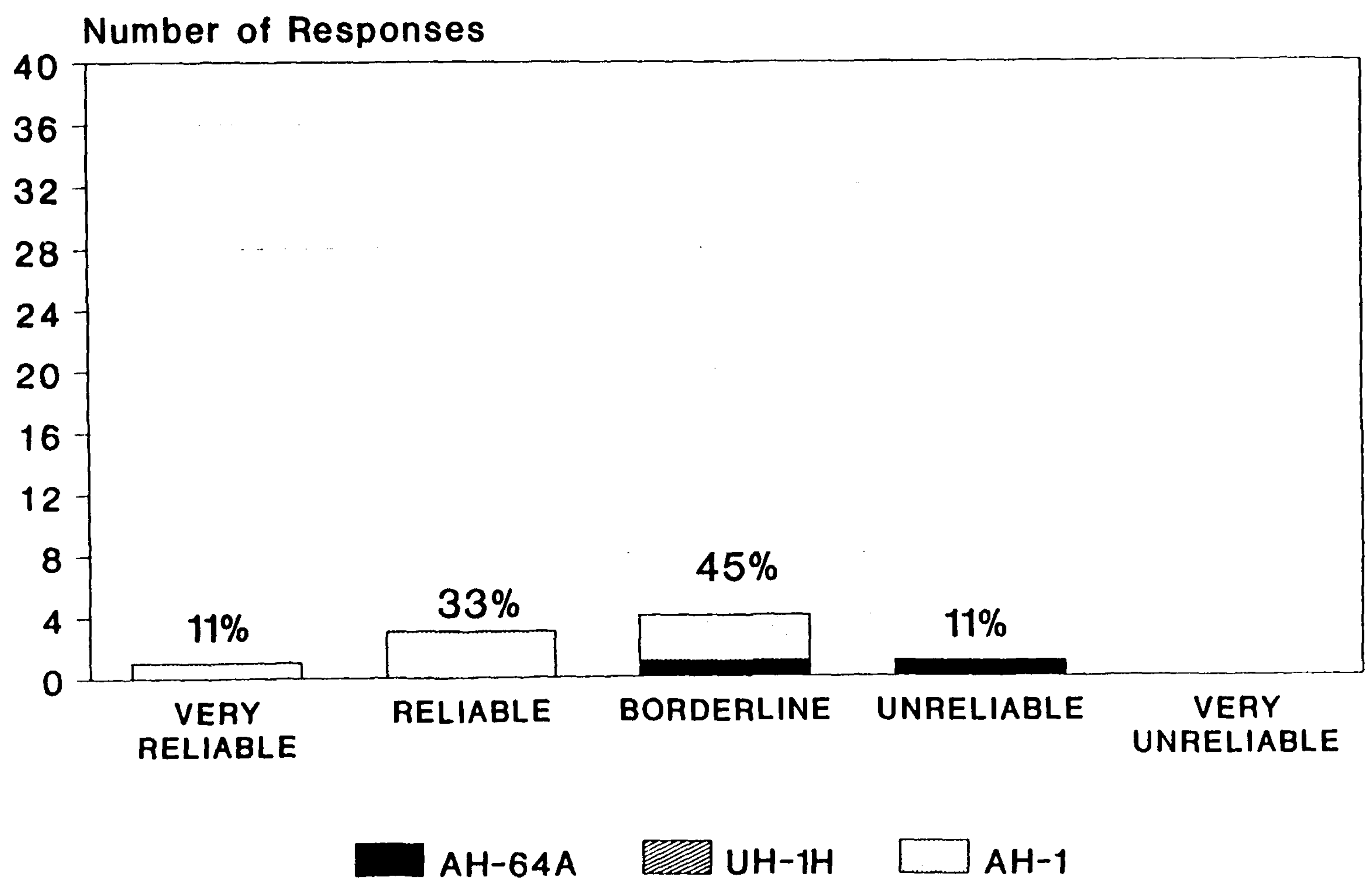
Flight Hours under 500 (N = 9)

Item 10. When CWS indicated that wires were in the vicinity, did you visually verify the presence/location of the wires before starting an evasive maneuver?



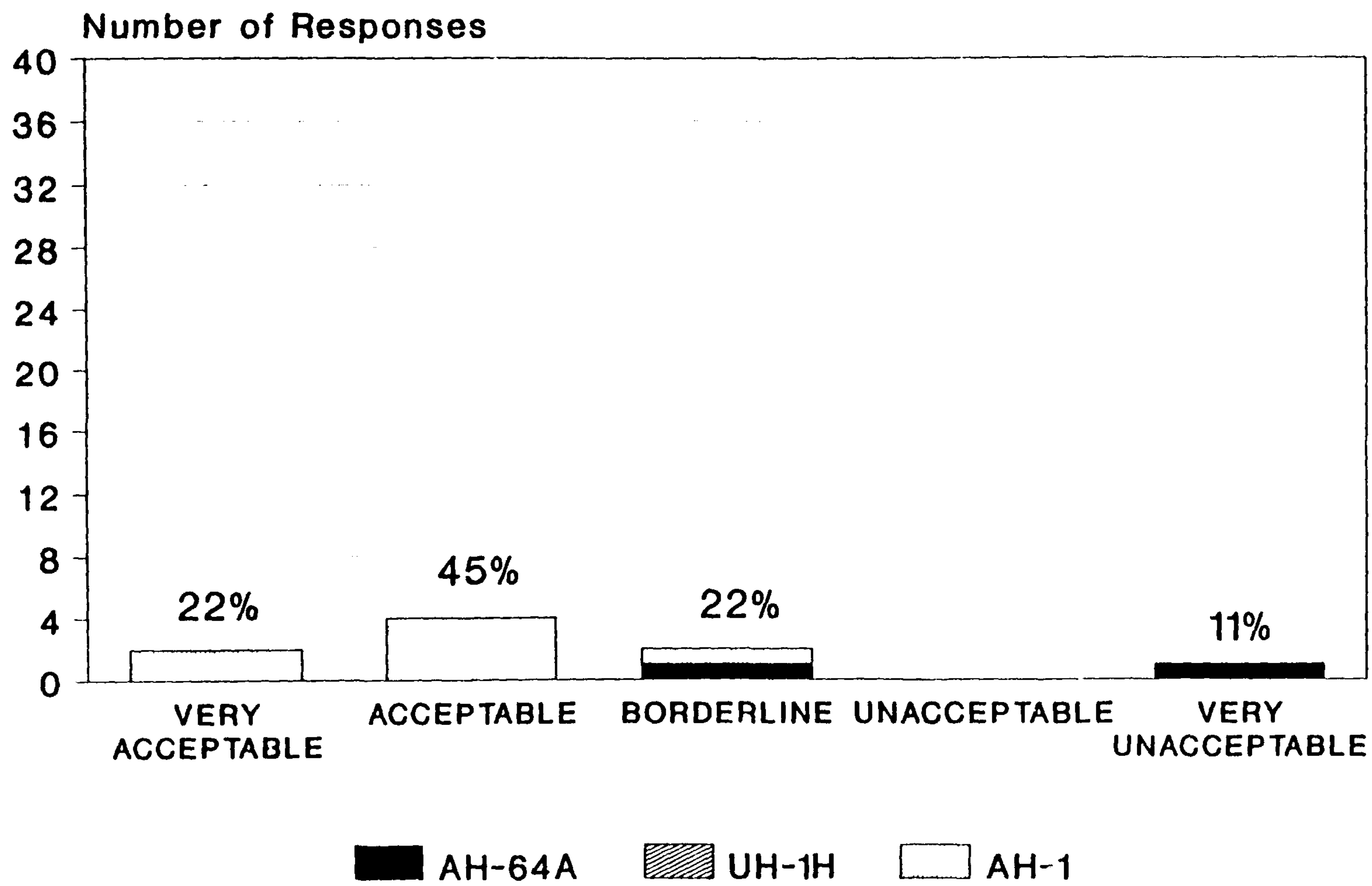
Flight Hours under 500 (N = 9)

Item 11. Was the CWS a reliable indicator that wires were in the vicinity (that is, when a wire is present, did the CWS provide an indication)?



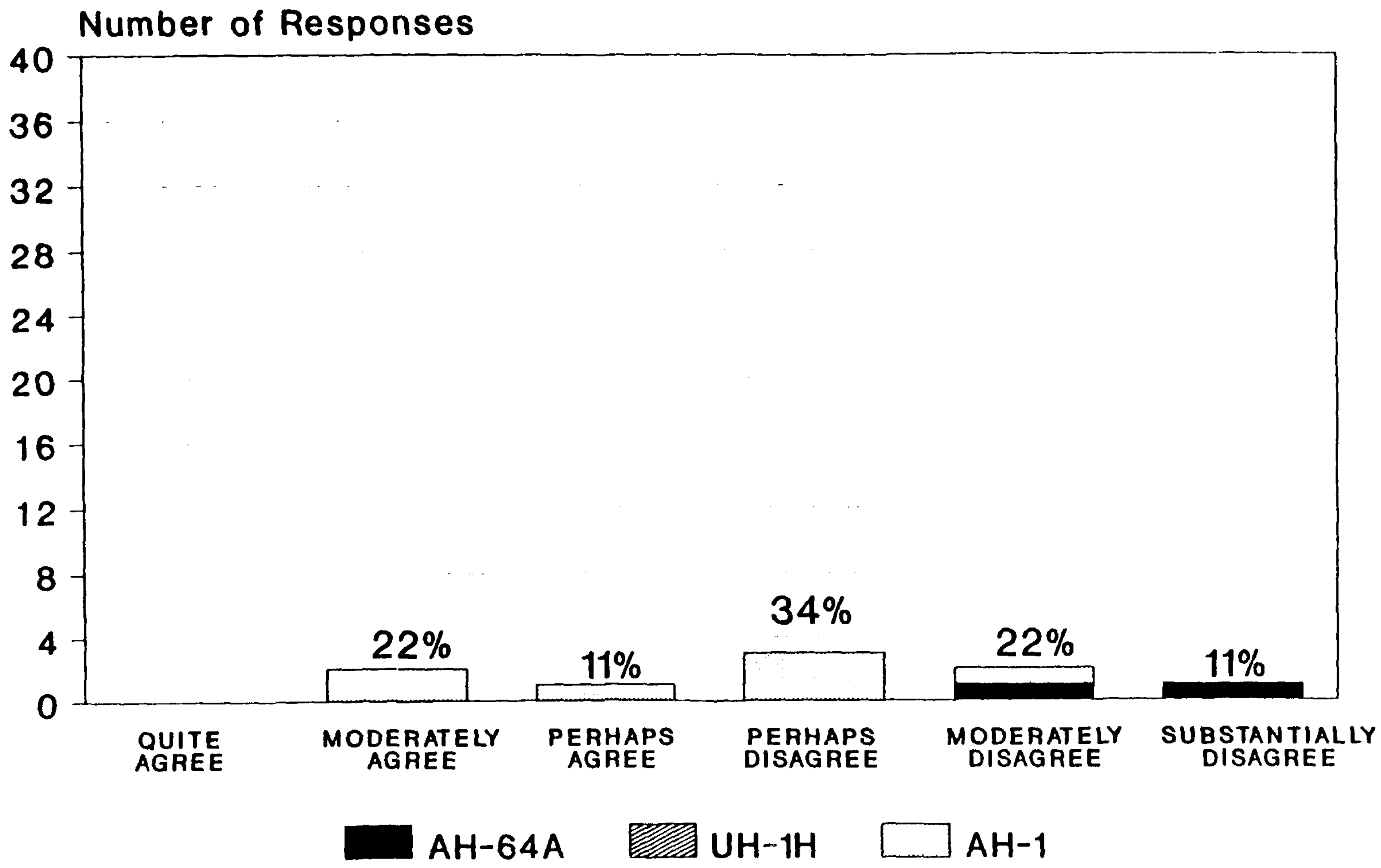
Flight Hours under 500 (N = 9)

Item 12. Evaluate the false alarm rate of the CWS (a false alarm is when the CWS indicates wires are present, but no wires are in the vicinity).



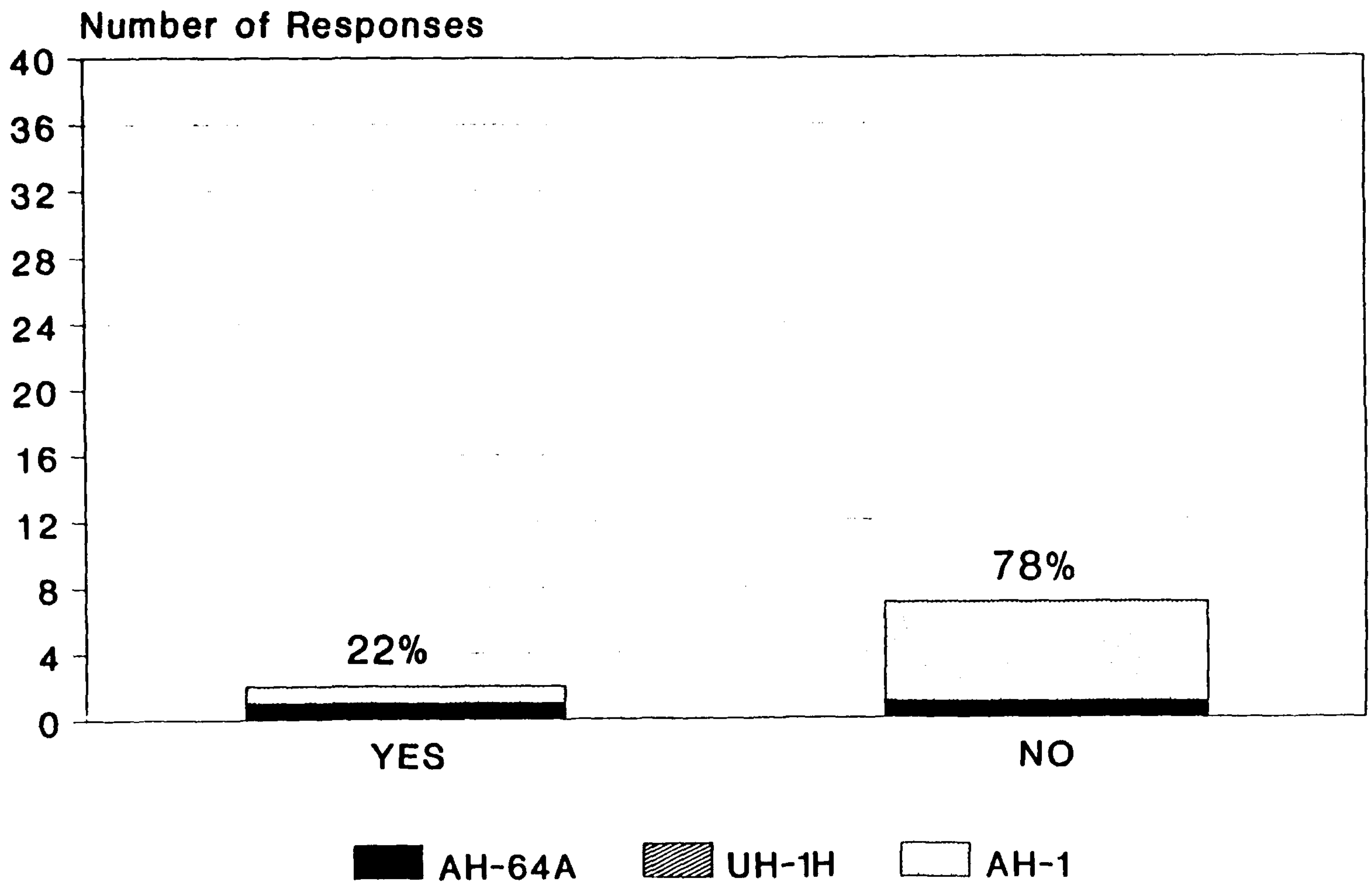
Flight Hours under 500 (N = 9)

Item 13. The CWS will help to provide a substantial reduction in helicopter wire strike accidents.



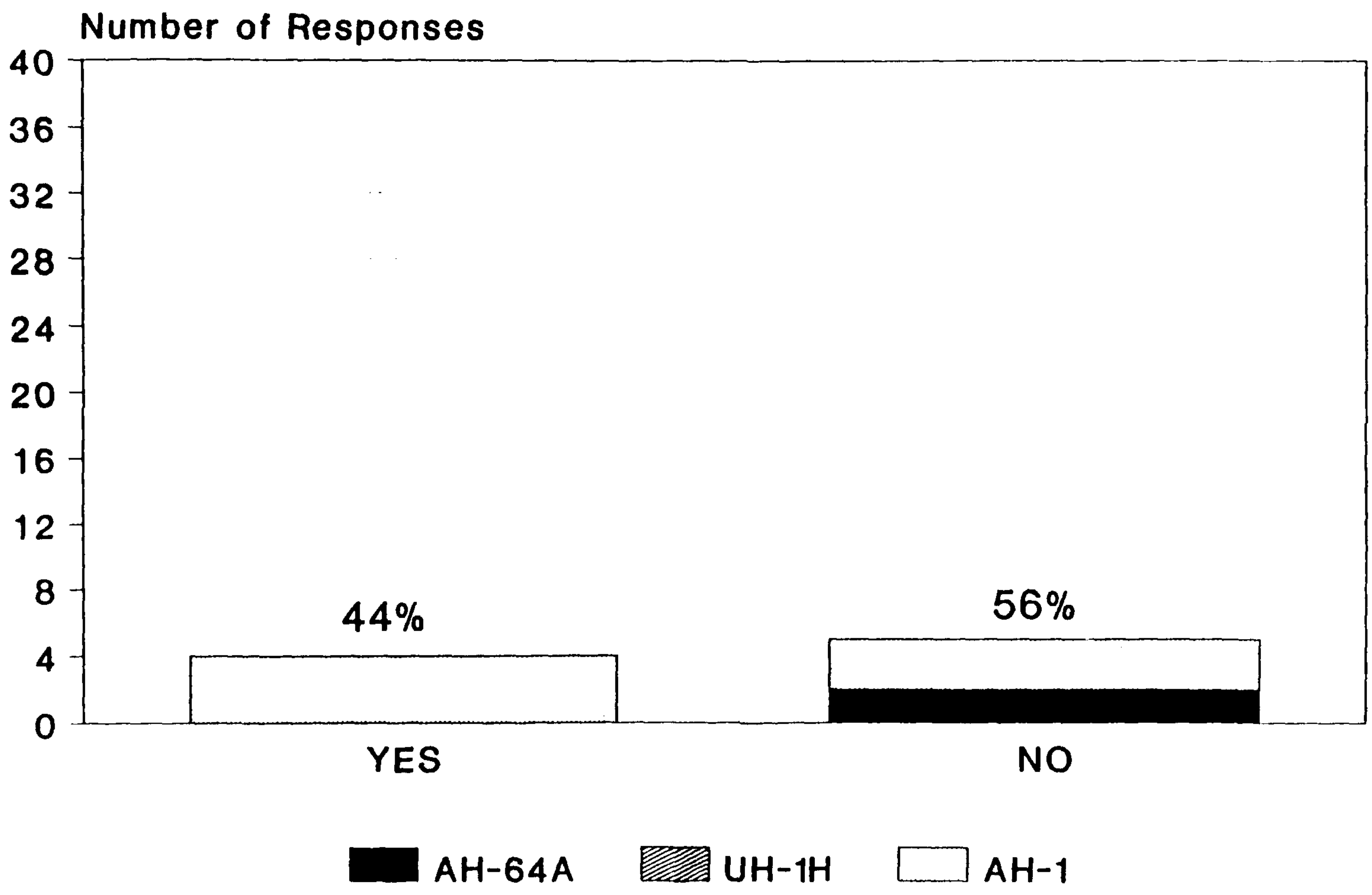
Flight Hours under 500 (N = 9)

Item 14. Is the CWS display lacking any information that is needed to make the system more effective?



Flight Hours under 500 (N = 9)

Item 15. Overall, do you believe that the CWS will help aviators avoid wire strikes?

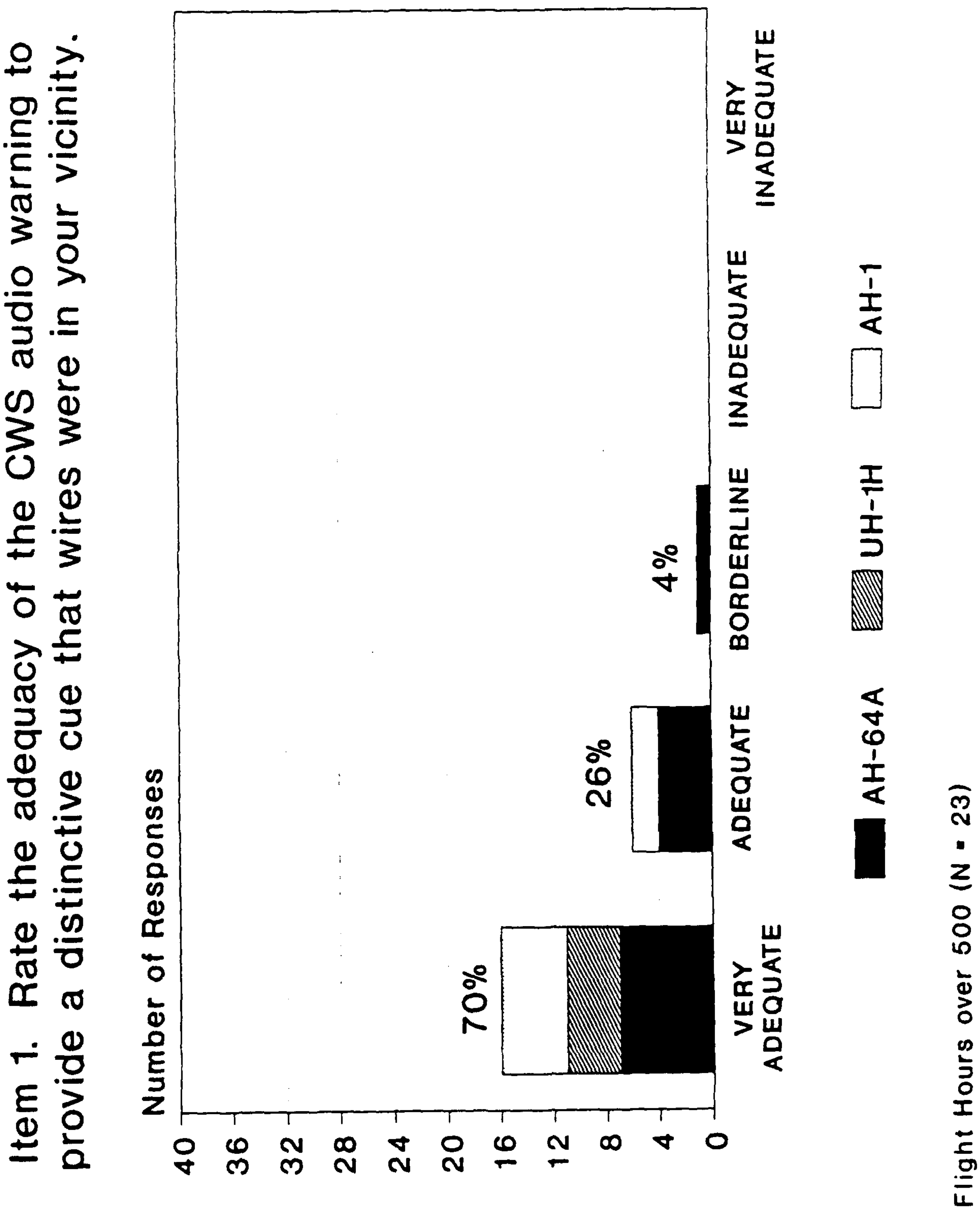


Flight Hours under 500 (N = 9)

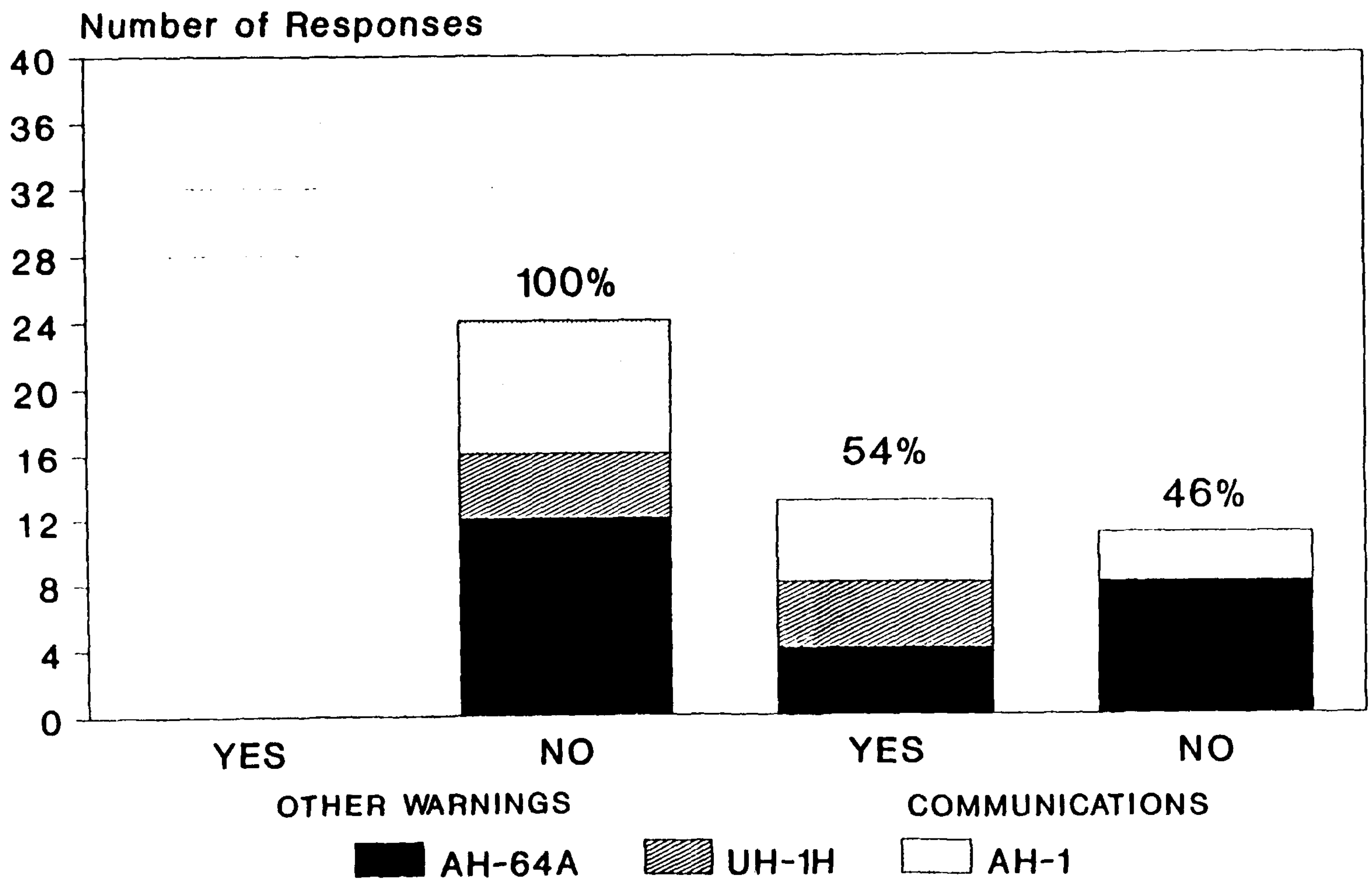
APPENDIX F

RESULTS OF CWS QUESTIONNAIRE FOR PILOTS HAVING TOTAL FLIGHT HOURS OVER 500

(24 Participants)

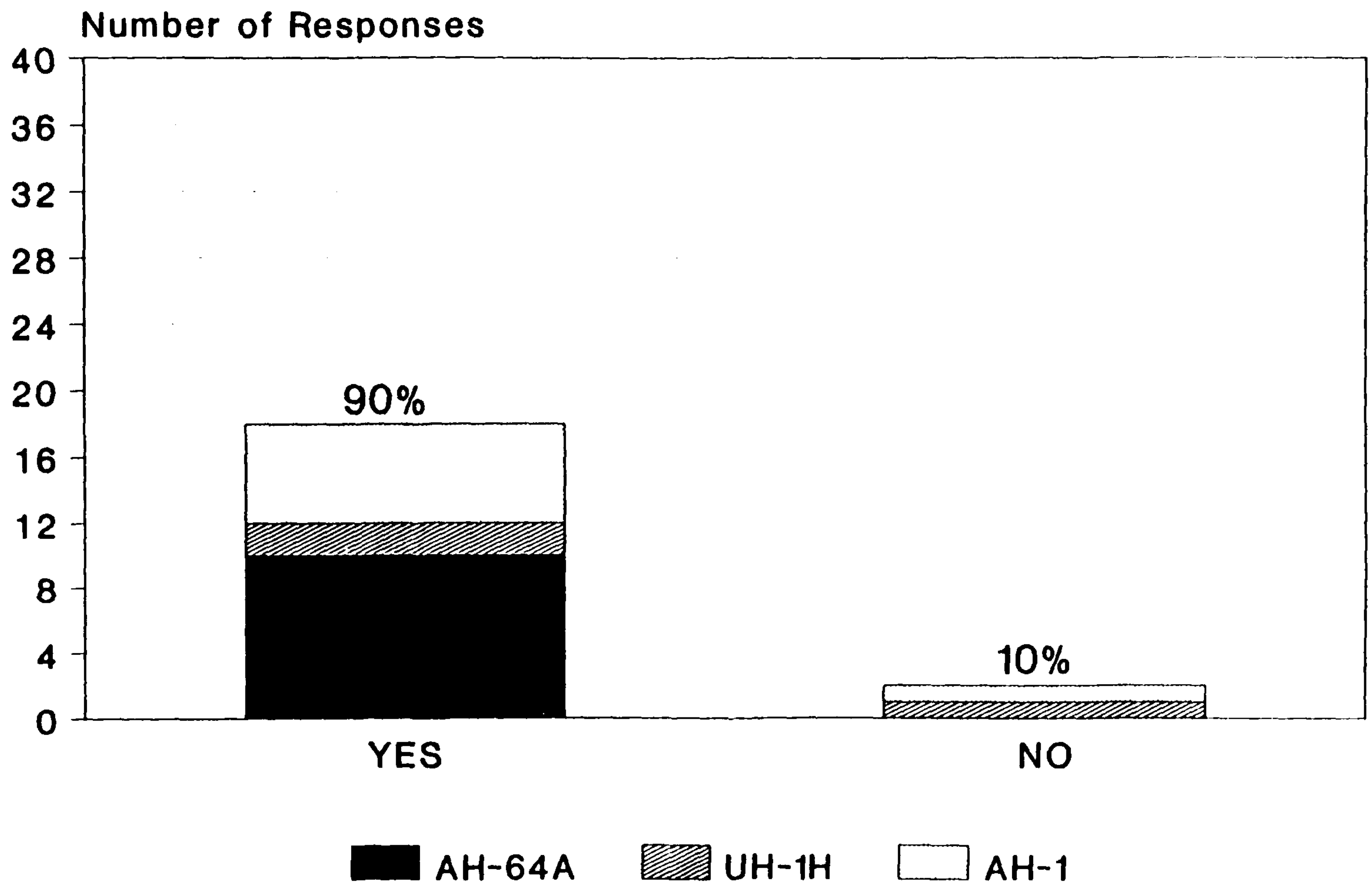


Item 2. Did the CWS audio warnings interfere with other audio warnings or with communications?



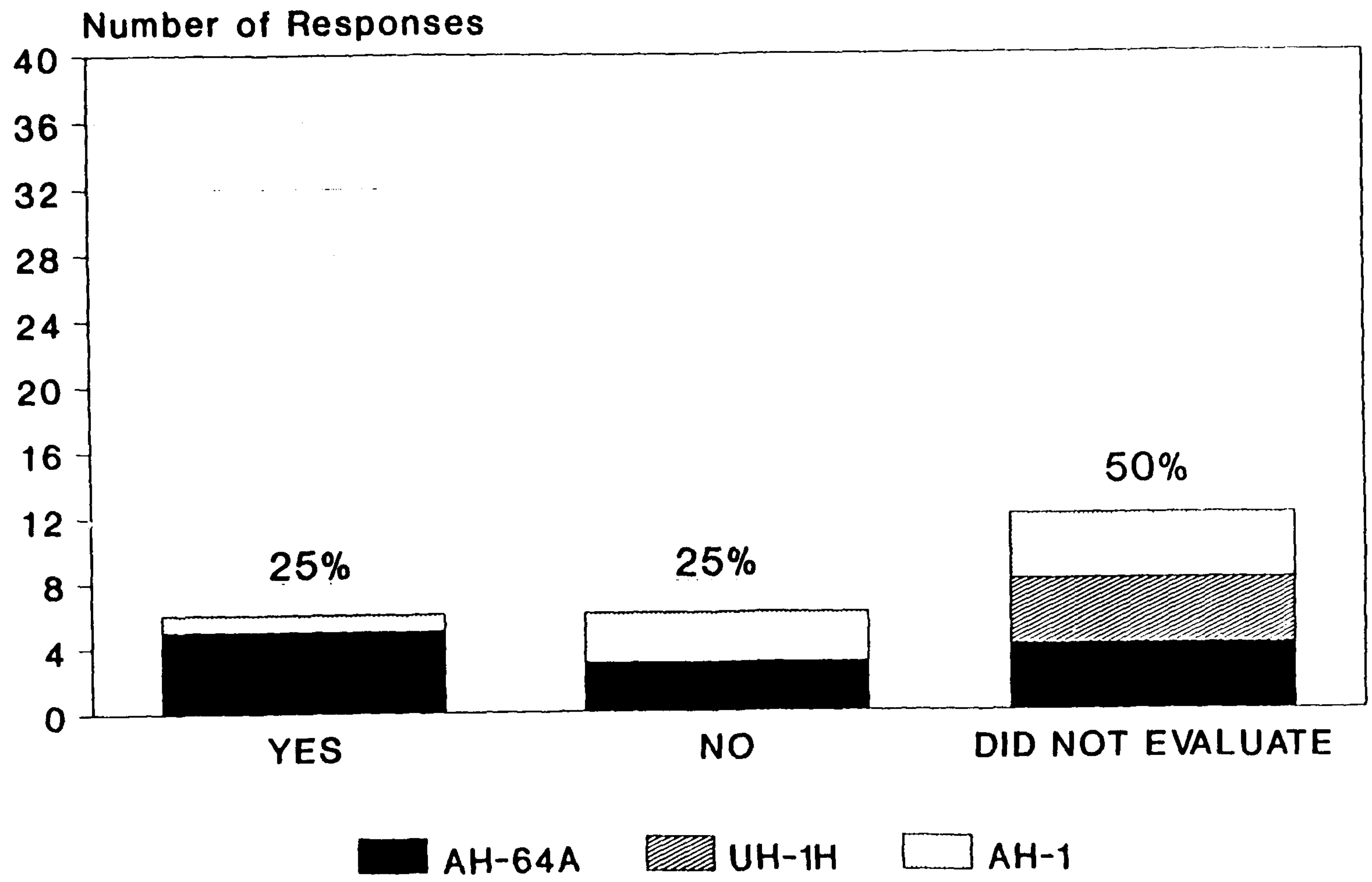
Flight Hours over 500 (N = 24)

Item 3a. Were the CWS display lights easily seen in direct sunlight?



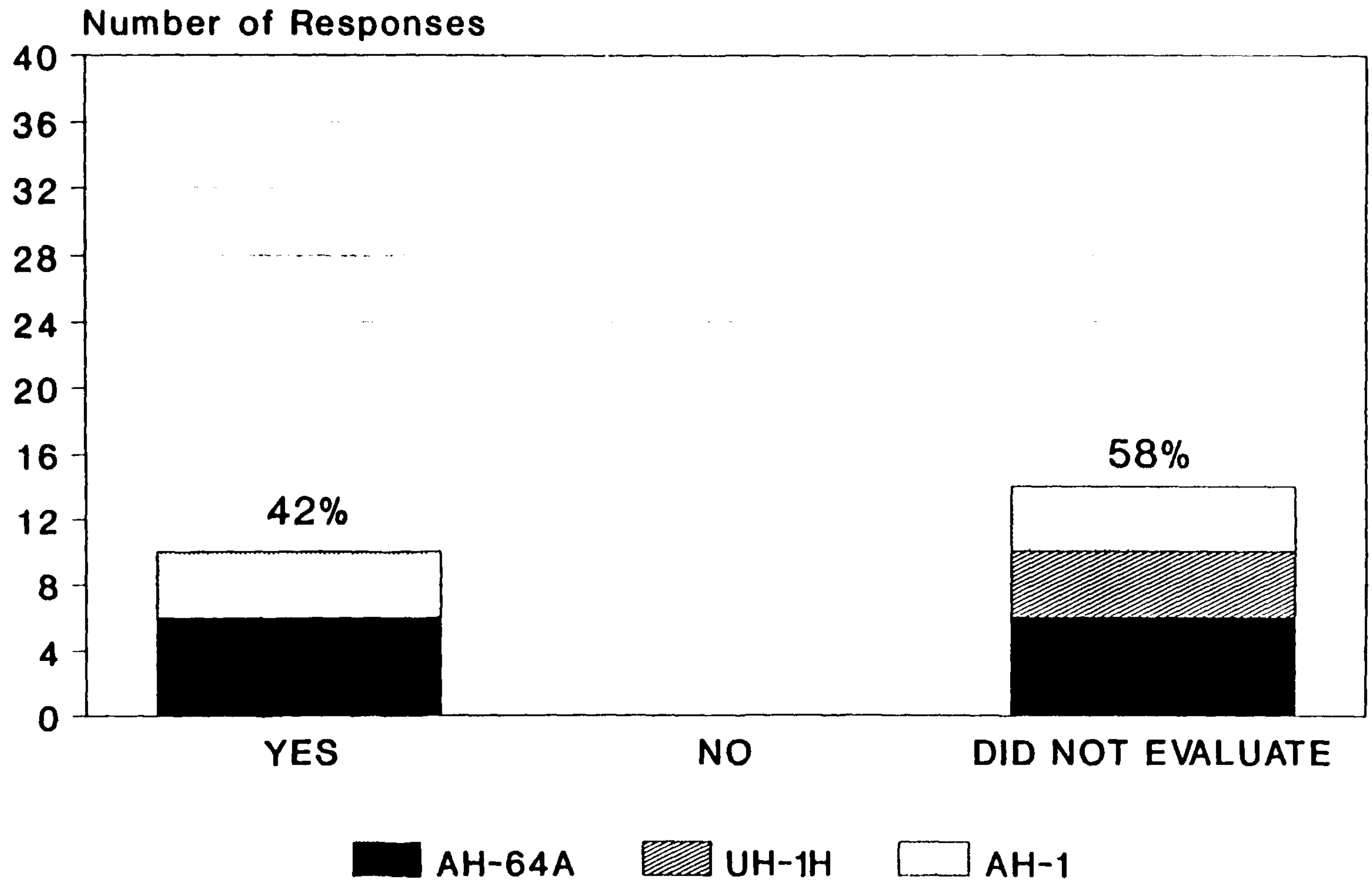
Flight Hours over 500 (N = 20)

Item 4. Was the CWS display location usable when wearing night vision goggles or the helmet mounted display?



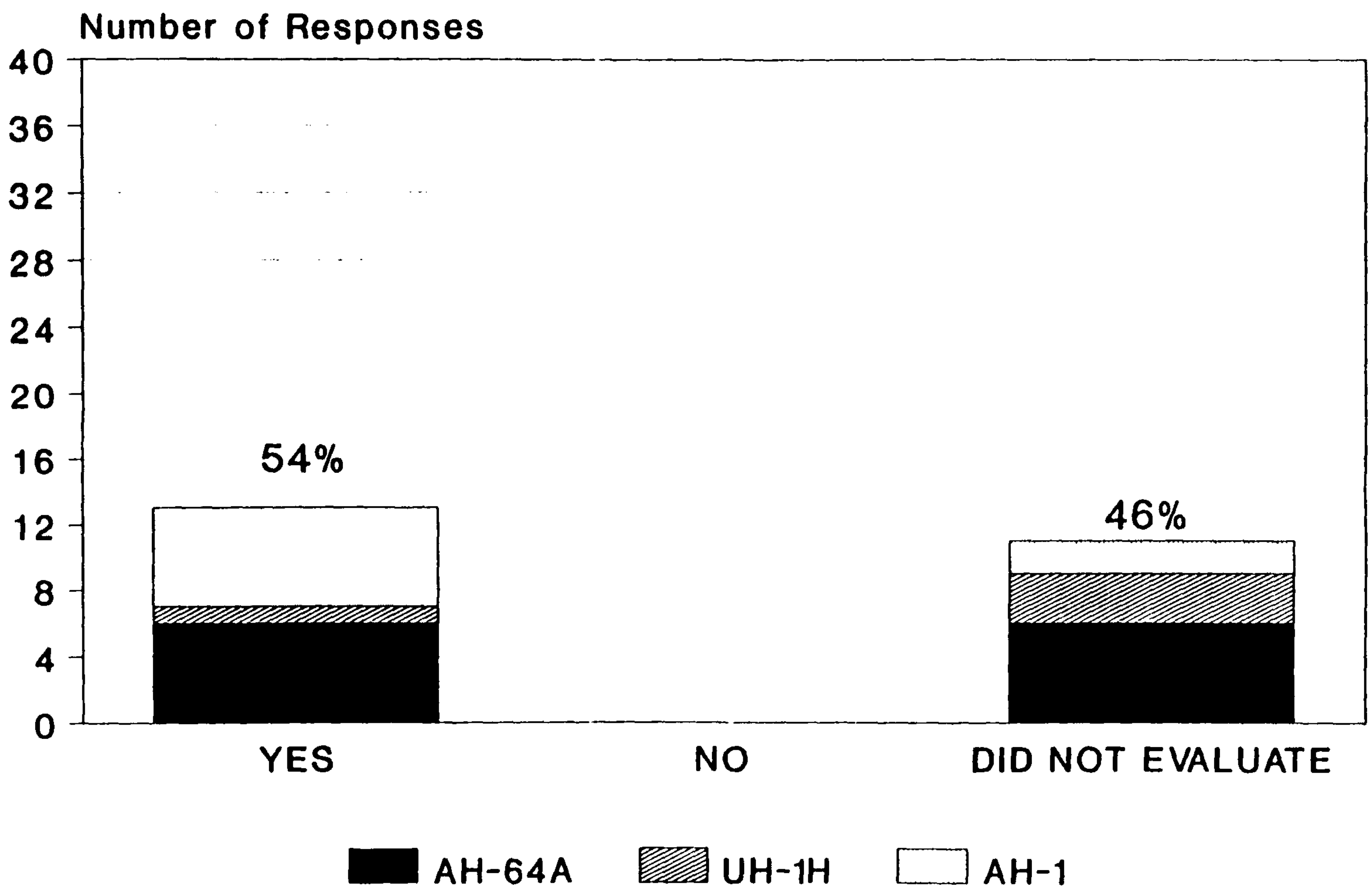
Flight Hours over 500 (N = 24)

Item 5. Were the CWS lights NVG/HMD compatible?



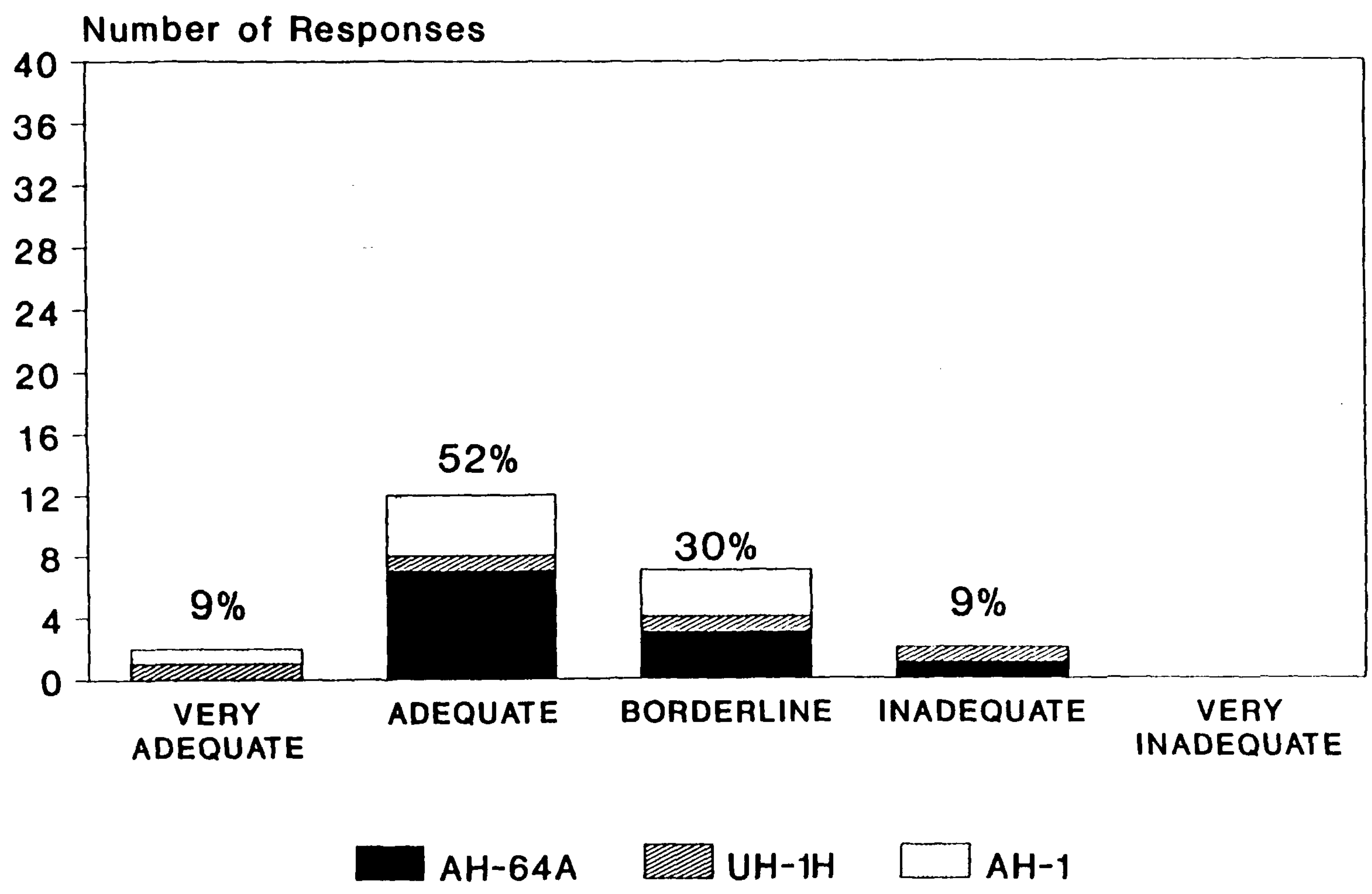
Flight Hours over 500 (N = 24)

Item 6. Were the CWS lights adequate for use during night unaided flight?



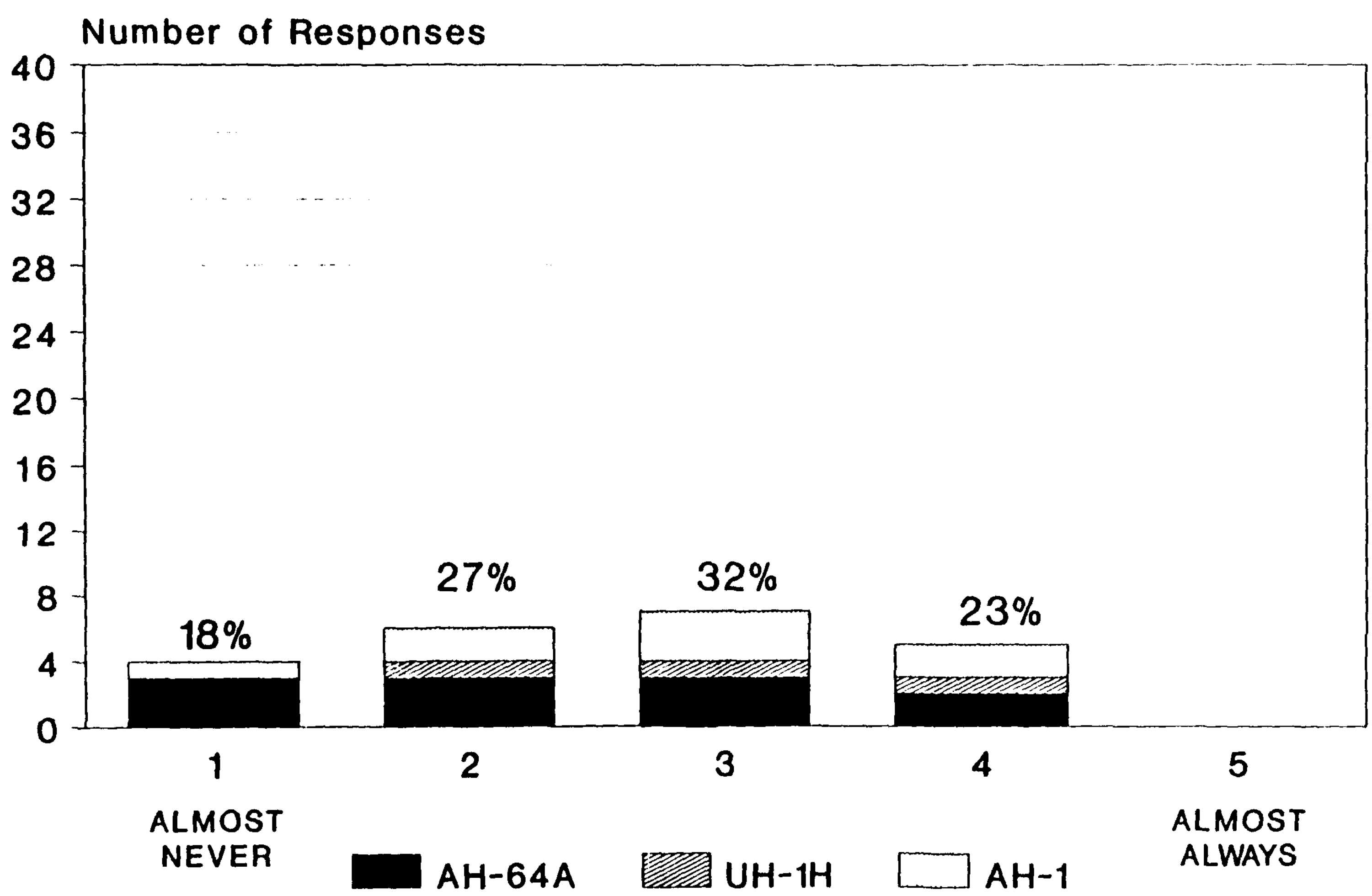
Flight Hours over 500 (N = 24)

Item 7. Did the CWS provide adequate information for you to determine the relative bearing to the wires?



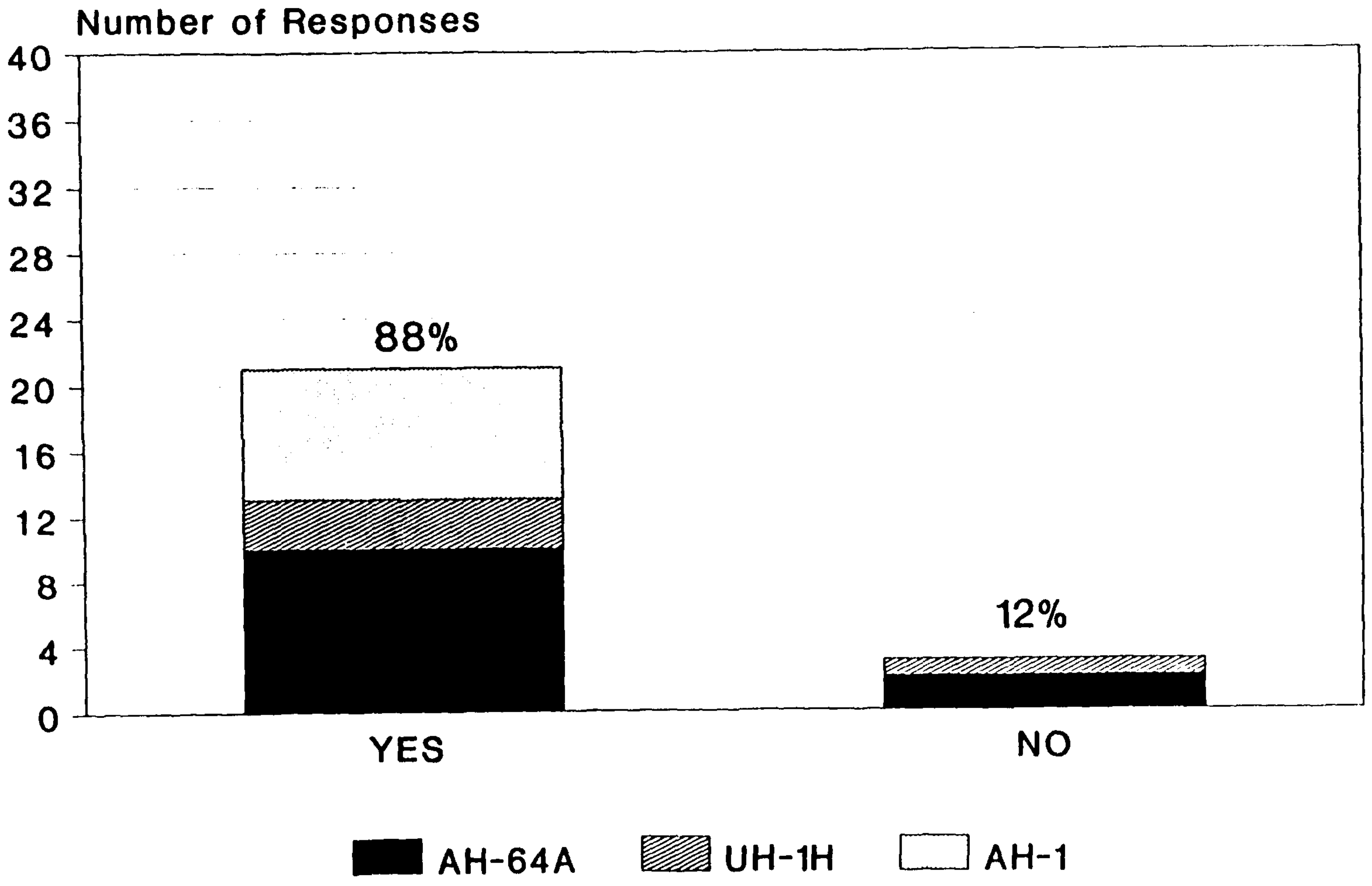
Flight Hours over 500 (N = 23)

Item 8. In general, did the CWS warn you of the presence of wires in sufficient time to successfully perform an avoidance maneuver?



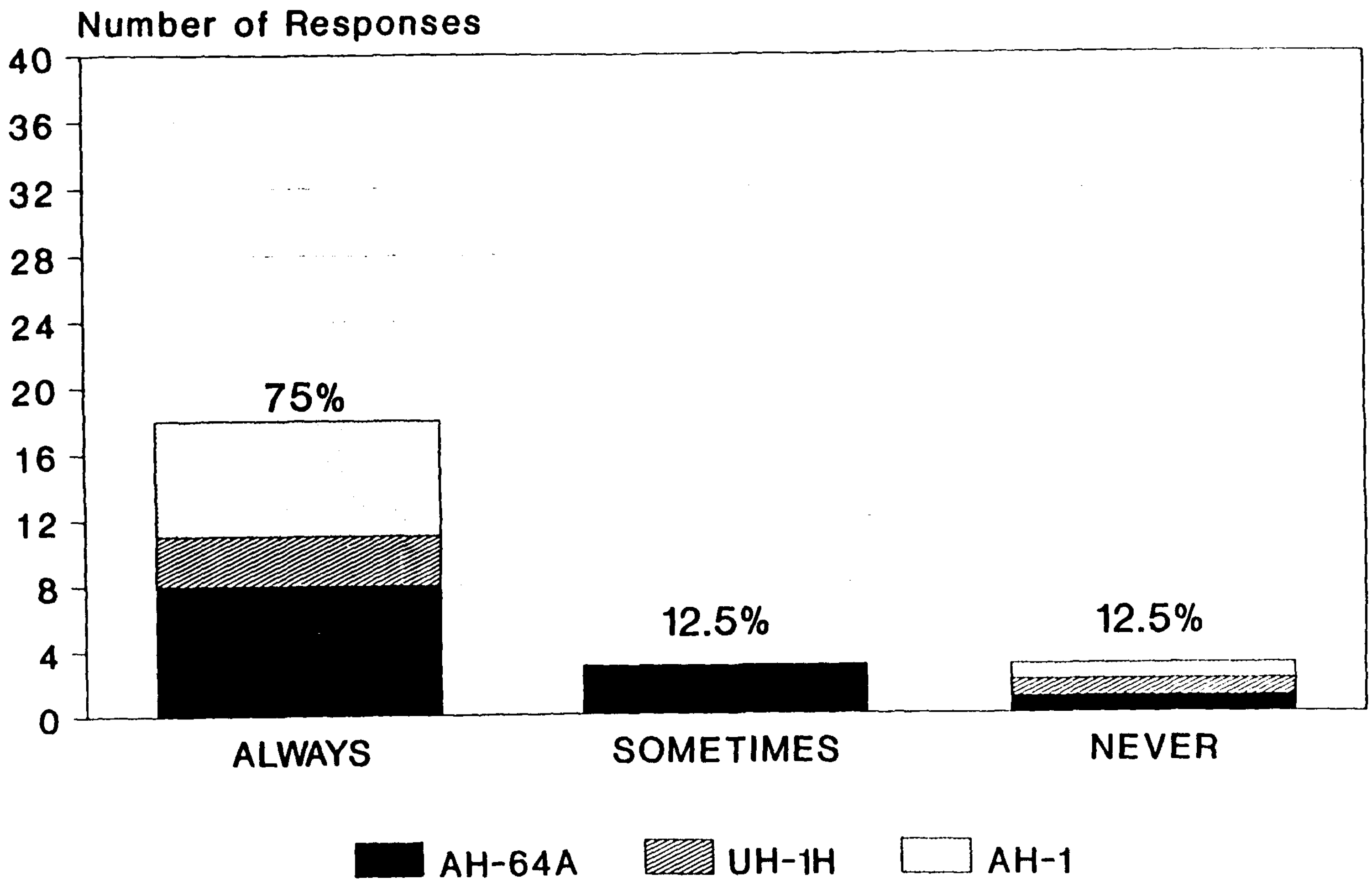
Flight Hours over 500 (N • 22)

Item 9. Was there ever a case where CWS did not warn you in time to successfully perform an avoidance maneuver?



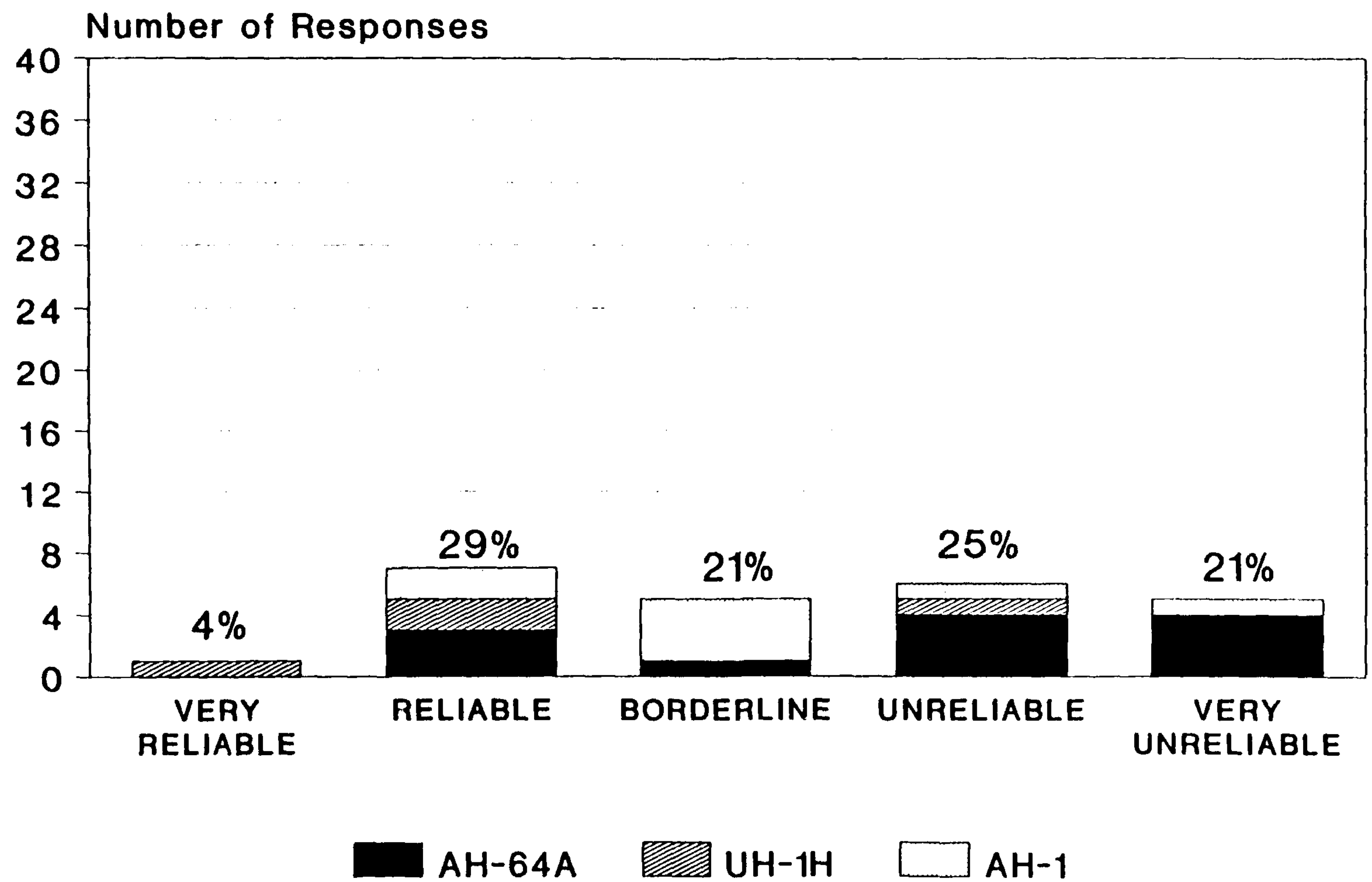
Flight Hours over 500 (N = 24)

Item 10. When CWS indicated that wires were in the vicinity, did you visually verify the presence/location of the wires before starting an evasive maneuver?



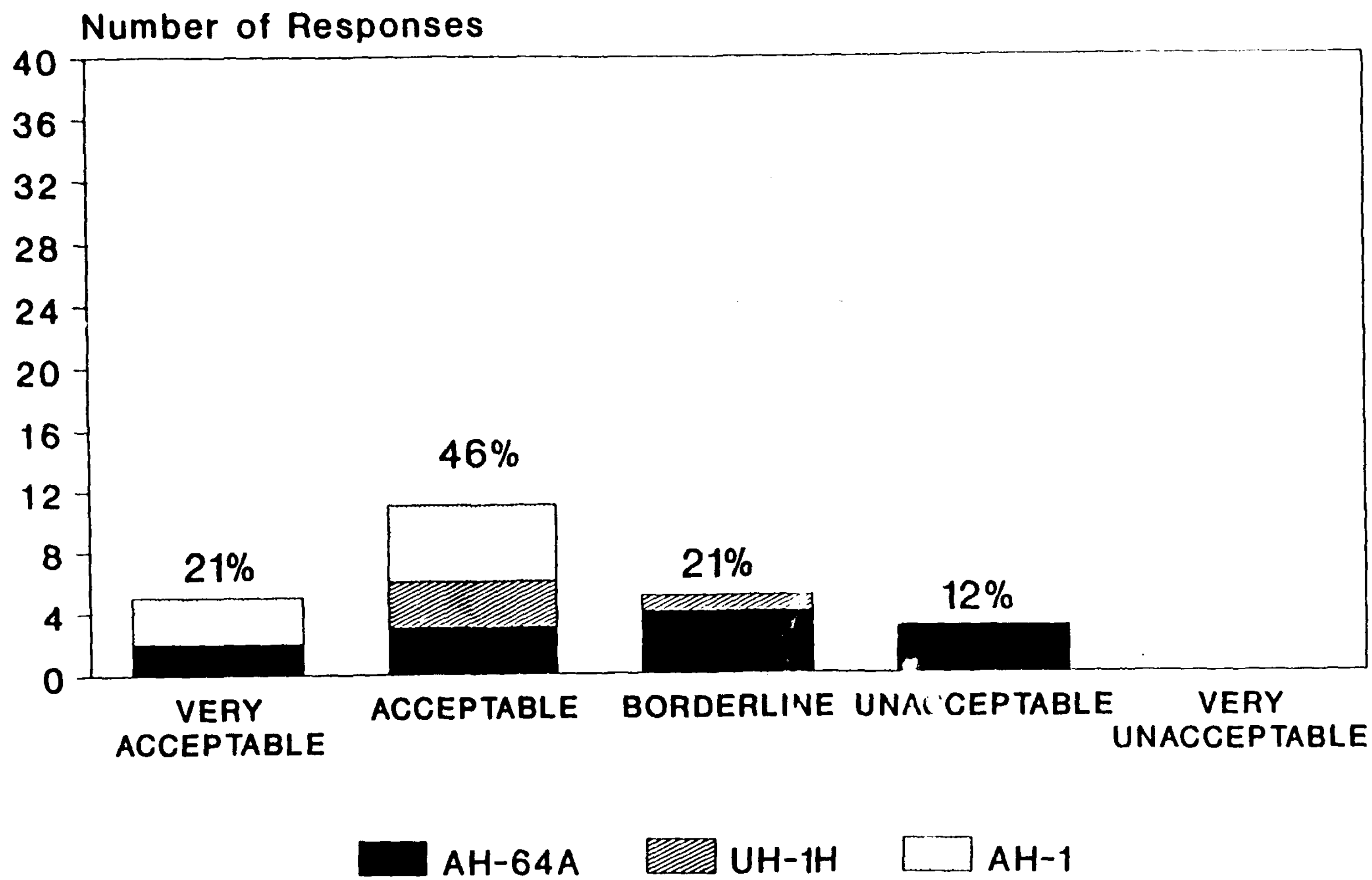
Flight Hours over 500 (N = 24)

Item 11. Was the CWS a reliable indicator that wires were in the vicinity (that is, when a wire is present, did the CWS provide an indication)?



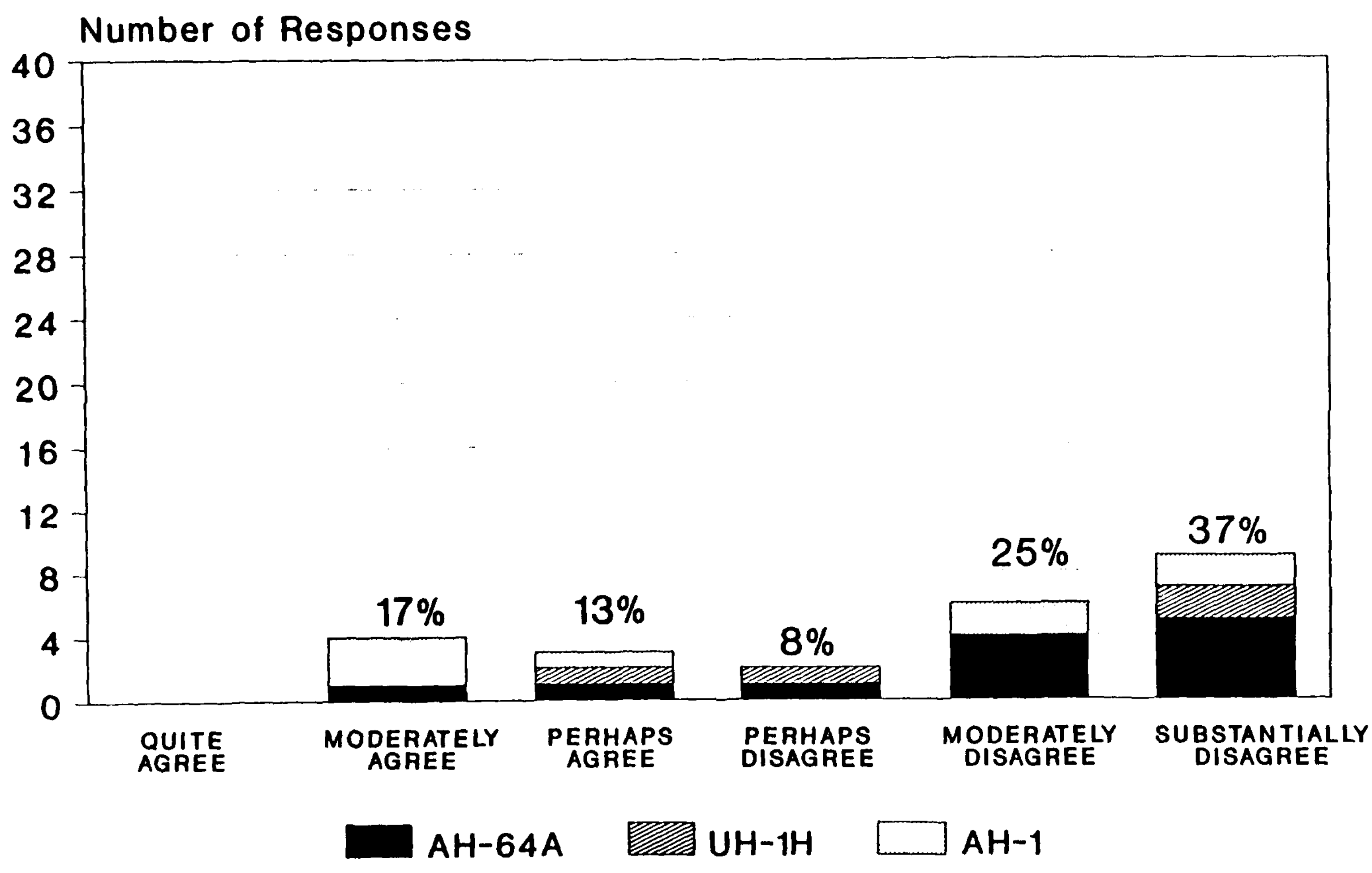
Flight Hours over 500 (N = 24)

Item 12. Evaluate the false alarm rate of the CWS (a false alarm is when the CWS indicates wires are present, but no wires are in the vicinity).



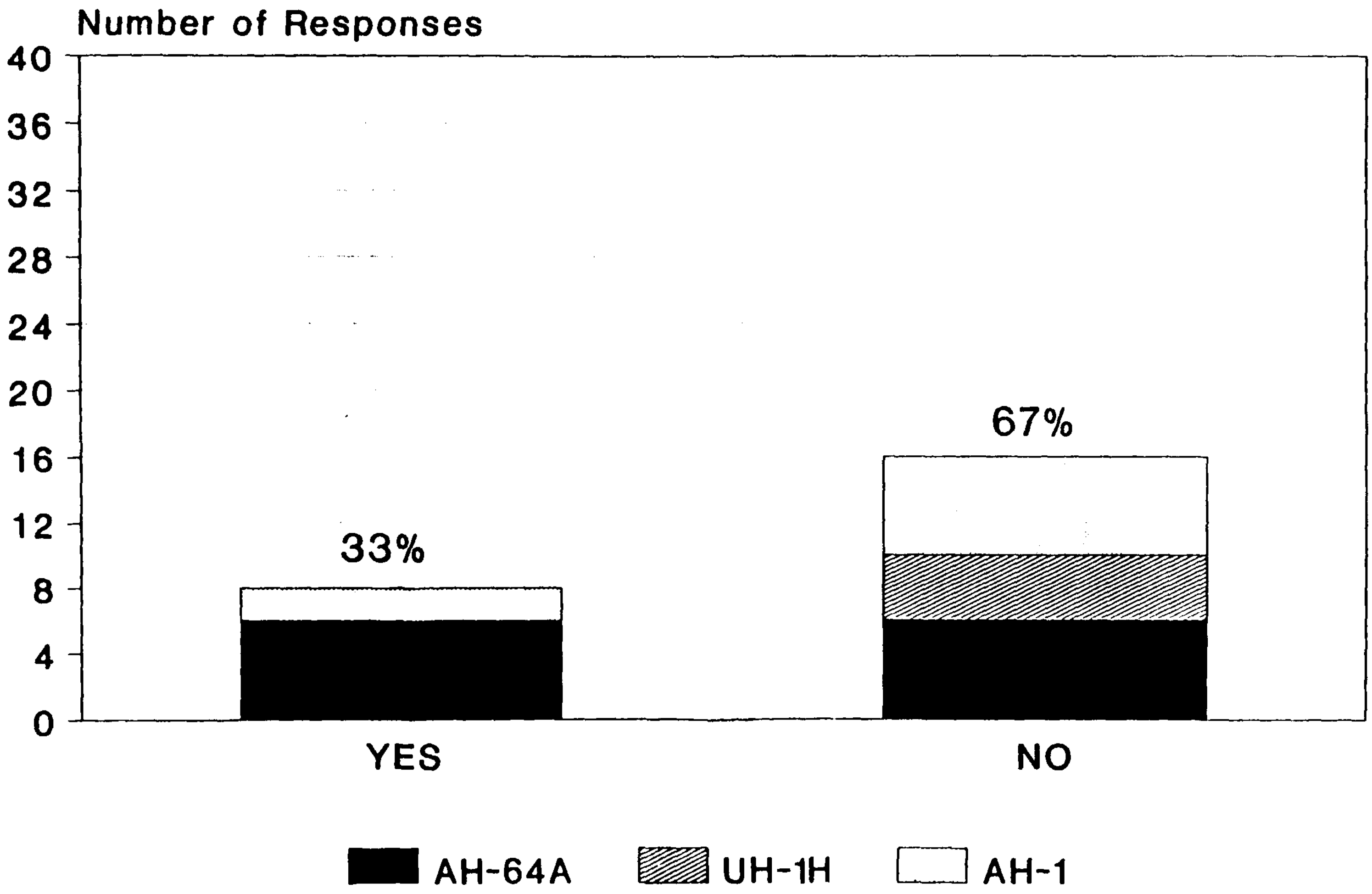
Flight Hours over 500 (N = 24)

Item 13. The CWS will help to provide a substantial reduction in helicopter wire strike accidents.



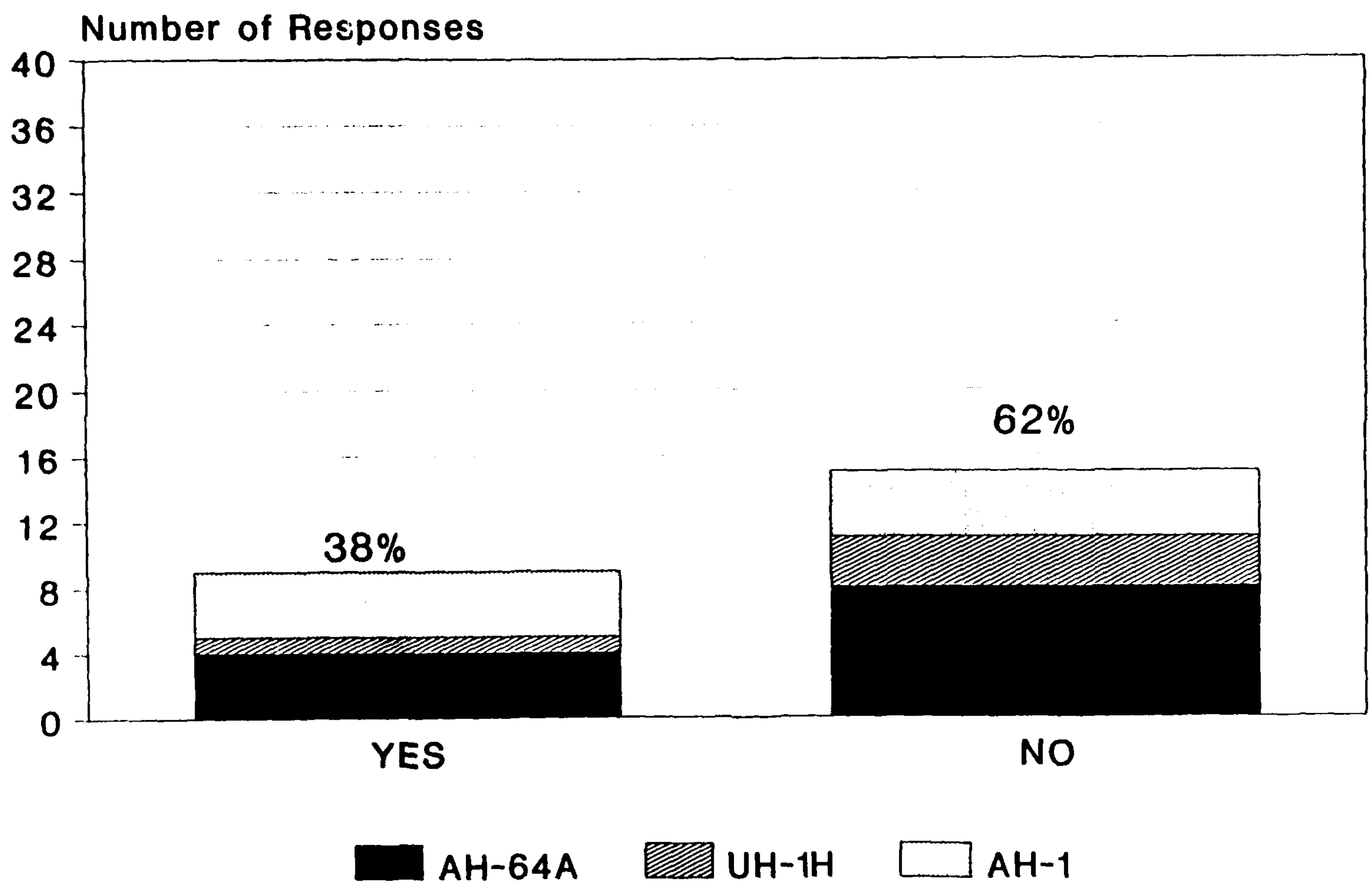
Flight Hours over 500 (N = 24)

Item 14. Is the CWS display lacking any information that is needed to make the system more effective?



Flight Hours over 500 (N = 24)

Item 15. Overall, do you believe that the CWS will help aviators avoid wire strikes?



Flight Hours over 500 (N = 24)